Milan European Economy Workshops

THE FINANCING HISTORY OF URBAN WATER INFRASTRUCTURE IN PARIS (1807-1925): LESSONS FROM THE PAST TO ENLIGHTEN PRESENT AND FUTURE CHALLENGES?

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Working Paper n. 2012-22

Novembre 2012

JEAN MONNET CHAIR

Economics of European Integration

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XI Milan European Economic Workshop
Università degli Studi di Milano, 22-23 giugno 2012

The financing history of urban water infrastructure in Paris (1807-1925) : lessons from the past to enlighten present and future challenges[1] ?

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Abstract

Sustainable financing is a major challenge for the water sector both in many developing countries where water and sanitation services are still in the expansion phase and in Europe where the water industry is faced to major investments needs too. To give more depth to the present policy debate a historical perspective on water services financing is needed. This paper is focused on the financing history of the Paris water infrastructure brought to completion in the 1807-1925 time frame (Ourcq canal, water supply network and sewers, long distance aqueducts, water treatment plants, waste water treatment units). A variety of financing schemes and institutional solutions (municipal budget - fiscal resources, concession, municipal bond and land added value capture schemes) are identified and described. A deeper analysis is made on the financial flows of Paris' water, sanitation and canals service over the 1893-1930 time frame. A discussion on the institutional choices and on the long run cost allocation of the chosen financing schemes is made. It appears that long term debt, inflation and land added value capture mechanisms played key roles in absorbing part of the investments' costs.

Keywords:

Financing history, Infrastructures, Water supply and sewerage, Paris, Municipalization, 3T's, cost sharing, bonds, inflation

JEL: H54 - H72 - H74 - L95 - N73 - N74 - N83 - N84 - N93 - N94

Acknowledgments

We wish to thank the Paris water operator *Eau de Paris* and the *Agence Nationale de la Recherche* (ANR) through the EAU&3E research project (http://eau3e.hypotheses.org) for their financial support. We are also grateful to all those who read and made comments on the earlier version of this paper.

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[1] An earlier version of this paper was presented at the XI Milan European Economy Workshop, June 22 - 23 2012.The MEEW was supported by the Jean Monnet Chair of EU Industrial Policy and the EIBURS program. The usual disclaimer applies.

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1 Introduction

In most developing countries water services are still in the early phase of development and network expansion. The water industry is very capital intensive and requires huge lump sum investments particularly in the early phase of ewpanding the infrastructure. In a historical perspective how to finance these investments has constantly been a major concern, not always easy to solve.

In the last ten years great attention has been given by international institutions and donors to the issue of sustainable financing for the water sector through various working panels[4]. This process led around the Istanbul 2009 World Water forum to the OECD publications (OECD 2009) clarifying concepts and defining a harmonized terminology on costs and financing sources well known as the "3T's" (Tariffs, Taxes and Transfers).

The issue was also picked up again in 2012 at the World Water Forum in Marseille where the whole "Condition for Success 2 -Financing water for all*"* was focused on the concepts of the 3T's and of "Sustainable Cost Recovery*"* (Tremolet 2012a; Tremolet 2012b). In those sessions many speakers made references to what were the financing solutions adopted in the past stating that "looking back at how water investments have been financed in the past can give us clues as to what solutions could be defined in the future" (Tremolet 2012a).

It should be pointed out however that sufficient and sustainable financing for water infrastructure is a crucial factor not only in developing countries where modern water services are still in an expansion phase but also in Europe where they are now a "mature industry[5] with an increasing need to reproduce the (huge) infrastructure capital which was set up over decades" (Barraqué 2009).

Indeed the sustainability of water services in Europe is presently challenged by two contradictory changes. On one hand, compliance with stricter sanitary and environmental standards and networks renewal's burden induce an increase in water costs. On the other hand water consumption is decreasing in many big cities such as Paris (Barraqué et al. 2011;

[4] Such as the ones chaired by Mr Camdessus and Mr Gurria which produced various reports (Van Hofwegen 2006; Winpenny 2003).

[5] Mr Gurria, General Secretary of OECD, also pointed out during his Marseille opening speech that " huge costs are now to be faced to replace and modernise ageing water infrastructure, and to upgrade systems to meet stricter quality standards" (Gurria 2012).

Souriau 2011). Water industry is characterised by costs which are mainly fixed while income is mainly proportional to sold volumes. The economical, social and environmental sustainability (as defined by Correia 2001; Barraqué 2003a; Barraqué 2005; Lejars and Canneva 2009) of water industry is thus jeopardized[6].

The present policy debate on the water sector is challenging. We believe that adopting a "long run" historical perspective on water financing can be highly beneficial to give more depth to the debate and enlighten present and future challenges both in developing countries and in Europe.

2 Water and sanitation infrastructure for the French capital city (1807-1925)

We chose to focus the present paper on the major expansion phase of modern water and sanitation infrastructure in Paris. Our historical analysis starts in 1807 with the construction of the Ourcq canal and ends in 1925 with the completion of the *Voulzie* operation, the last long distance aqueduct built in Paris.

In 1807 no more than 8000 m^3/day of drinking water were distributed by the Paris municipal water service for more than 546 000[7] inhabitants. Water was mostly pumped from the Seine through fire pumps (6833 m^3/day) even if some water also came from the *aqueduct d'Arcueil* and the *Sources du Nord* (respectively 960 and 288 m^3/day). 120 years later, in 1926, Paris water infrastructure allowed to deliver roughly 1 323 960[8] m^3/day to the 2 871 429 inhabitants. Indeed by 1925 a large part of Paris "modern" water infrastructure had been built.

In the beginning of the 19th century the first need was to bring large quantities of clean water to the city. This trend is analyzed by Bernard Barraqué as being part of the first of three engineering paradigms through which water industry history can be framed: a) "the paradigm of water quantity and water systems", b) "the paradigm of water treatment and water quality " and c) "the paradigm of environmental engineering" (Barraqué 2003b; Barraqué, Britto, and

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[6] The EAU&3E research project, seeks to analyze this major sustainability challenge (http://eau3e.hypotheses.org/) from various points of view (environmental, social, economic, governance). Our research is financed by the Paris water operator *Eau de Paris* in the framework of the EAU&3E research project.

[7] Population of Paris in 1801 (Bocquet, Chatzis, and Sander 2008)

[8] Including Ourcq water. The daily average amount without considering Ourcq water was of 1 087 852 m^3/day or 379 l/hab/day.

Formiga Johnsson). For instance, the first paradigm was the idea behind the construction in Paris of the *Canal de l'Ourcq* (section 3) and of the long distance gravity aqueducts which were built after 1862 (paragraphs 5.4, 5.5 and Table 11) to bring water from natural and unspoilt environments far from the city.

Once clean water was made available, the next step was to expand the water network to distribute it (firstly for free at public fountains, the so called "*Service Public*" and later through private connections "*à l'étage*", the "*Service Privé"*) and also to collect waste water with a sewer system (Table 5, Table 10, Box 3 and paragraphs 5.4 and 5.5). That sewer system was however not solving Seine's pollution issue: a waste treatment system had to be built (Box 3 and paragraph 5.5).

The main steps in the investment history of Paris's water infrastructure are summarized in the following table. Not only very different infrastructures were built but also a variety of financing tools (municipal budget - fiscal resources, concession, municipal bond and integrated urban development schemes) were adopted to support their cost.

Table 1 : Main phases in the investment history of the Paris water service in the 19th century, in grey investment phases which can be seen as examples of the "paradigm of water quantity".

Years	Investment phase	Historical phase	Comments
1803 - 1814	Ourcq phase 1	*Premier empire*	
1818-1822	Ourcq phase 2	*Restauration*	Private concession on the Canal de l'Ourcq and canal Saint Martin
1806-1823	Sewer system phase 1	*Premier empire* and *Restauration*	
1824 - 1839	Sewer system phase 2	*Restauration*	Mainly after 1831
1806 - 1848	Water distribution network phase 1	*Premier Empire* + *Restauration*	Mainly after 1831
1860	Annexion of the *banlieue* within the Paris municipality and *régie interessée* with the *Compagnie Générale des Eaux*		
1862 - 1925	Gravity aqueducts and tanks	*Second empire* and *Troisième République*	Dhuis, Vanne, Vigne et Avre, Loing et Lunain, Voulzie
1853 - 1880	Water distribution network phase 2 + sewer system phase 3	*Second empire* and *Troisième République*	Within Paris's urban transformation
1853-1925	Surface water treatment plants	*Troisième République*	Mainly after 1878
1886 - 1925	Water distribution network phase 3 + Sewer system phase 4 + Waste water treatment through land farming	*Troisième République*	Especially after the 1894 *tout-à-l'égout* law

Source : author's elaboration

Section 3 focuses on the Ourcq canal operation, section 4 deals with the water distribution networks until 1853 while Section 5 analyzes investments undertaken between 1853 and 1925. For each kind of infrastructure we detail the financing scheme chosen and its implication. In section 6 we discuss the long-run cost allocation between the various stakeholders. For each "short run financing solution" who is the long run end payer?

To address such a key issue, it is essential to give great attention to the institutional management and ownership paths of the water services through the time. The main steps in the institutional history of Paris water service are summarized in the table below. The institutional choices made to build and operate water infrastructures in our time frame vary from full public provision under the Emperor's will (Ourcq phase 1 - paragraph 3.1) to private concession for the canals (Ourcq phase 2 – paragraph 3.2) with a recurrent public-private debate on the opportunity to award a concession for water distribution or not (Box 2, paragraph 3.3 and section 4). The peculiar arrangement of a mixed scheme (Municipal department plus *régie interessée* with the *Compagnie Générale des Eaux* - CGE), which incredibly lasted for more than 120 years (1860 – 1984), is discussed in section 4.

Table 2 : Main steps in the institutional history of the Paris water service, in grey the phases on which this paper is focused.

Years	**Institutional phase**	**Water production and transport**	**Water distribution**	**Sanitation**	**Comments**
1807 - 1860	Pure municipal service	Municipal department	Municipal department (mainly through public fountains	Not existing yet (but already drainage)	Private concession on the Canal de l'Ourcq and canal Saint Martin
1860 – 1984	Mixed scheme	Municipal department	Municipal department + *régie intéressée* with the *Compagnie Générale des Eaux* (CGE)	Municipal department, progressively with intermunicipal cooperation	
1985 – 1986	Transition scheme	Municipal department	Private companies *CGE* and *Lyonnaise*	Municipal department + SIIAP at the intermunicipal scale	
1987 – 2009	Delegation scheme	SAGEP (PPP)	Private companies *CGE* and *Lyonnaise*	Municipal department + SIIAP at the intermunicipal scale	SAGEP (70 % of shares owned by the city of Paris and 28 % of the shares owned by *CGE* and *Lyonnaise)*
After 2009	Municipalization	Eau de Paris	Eau de Paris	Municipal department + SIIAP at the intermunicipal scale	

Source : author's elaboration

3 The Paris canals : from public provision to concession and swinging back again

3.1 Canal de l'Ourcq – phase 1 – Wine for water according to the Emperor's will

The purpose of the Ourcq canal project was not only to bring drinkable water to the city but also to allow navigation and transport of goods. The 29th *Floréal an X* (May 19th 1802) a law authorizing the project was passed after being approved by *Napoléon Ier*. A few months later, the *25th Thermidor an X* (August 13th 1802), a decree established for the next ten years an additional levy of 1.25 franc per hectolitre of wine entering the city of Paris (*droit d'octroi).* Revenues from this levy were entirely allocated to the Ourcq canal project (Beaumont-Maillet 1991, 142).

Box 1 : The French and Paris fiscal context in the 19th century

At the national scale most of the national tax systems in Europe in the 19th century were still based mainly on indirect taxes with a strong redistributive effect in favour of capital owners and upper revenue classes (Ardant 1976). In France (and elsewhere in Europe too) it was only at the end of the 19th century that the switch from an indirect tax system towards an income tax took place together with a necessary shift towards a fairer and progressive[9] tax allocation (Ardant 1976).

At the municipal scale the *droit d'octroi,* a consumption tax on commodities entering a city, constituted in the 19th century the majority of municipal revenues in France and in other European countries (Ardant 1976). In Paris the *droit d'octroi* had been abolished after the Revolution in 1791 and established again in 1798 since no other replacement revenue could be found. It was then outlawed only in 1897. All along the 19th century indirect taxes provided on average more than two thirds of Paris's municipal revenues (Cadoux 1900).

Construction started as soon as in 1803 in order to satisfy Napoleon's will, but was initially carried out very slowly due to a harsh conflict on various technicalities of the project between *Pierre-Simon Girard,* the chief engineer appointed by *Napoleon I,* and the *Conseil Général*

[9] In fact a properly progressive income tax was introduced in France only after the First World War with the ideas from Joseph Caillaux.

des Ponts et Chaussées[10]. The rhythm of works sped up only after 1806 when an agreement was found on the project (Girard 1804; Cebron de Lisle 1991, 134).

Works were undertaken by various private contractors selected through bidding on unit price series (governmental decree of the *19 ventôse an XI* – 10 march 1803). In 1806 nearly 1800 workers were employed in the yards. Additional working force contributed to the project within the framework of "charity workshops" (growing from 100 people in 1805 to 900 in 1806). In 1808 some war prisoners contributed too in order to make the water flow through the canal and reach the *Bassin de la Villette* allowing the celebration party in the Emperor's honour *(2 Décembre 1808)*. However, works had been undertaken in such a hurry and with low quality standards to satisfy the Emperor's will that a few month later the *Bassin de la Villette* was again without water. Additional works had to be undertaken (Beaumont-Maillet 1991, 143).

Money coming from the additional *droit d'octroi* on wine was not sufficient to cover all the expenses, therefore the 21st March 1808 a decree enacted the sale of various navigation canals through France and allocated 3 million of francs of this sale to the Ourcq project (Beaumont-Maillet 1991, 143).

Notwithstanding this additional money, the city was struggling to cover the expenses, particularly the expropriation compensation fees which were increasing due to a windfall effect. Additional funding was needed. In 1810 the city was authorised to subscribe a 7 million loan (decree of the 21st February 1810) to buy the parcels of land needed both for the canal and the water distribution network. In fact this loan was never subscribed (Massa-Gille 1973). Works stopped in 1814 due to the undergoing events (Cebron de Lisle 1991, 135).

In 1816, after the *Restauration,* a special commission of the *Ponts et Chaussees* wrote a progress and status report (Conseil Général des Ponts et Chaussées 1816) which gives an interesting snapshot of the executed works which had already absorbed 22 million of francs.

This first phase of the Ourcq project appears to be essentially run by the Emperor's will and authority to which the city institutions were subjected[11]. The funding came mainly from the

[10] In fact *Napoleon I* had appointed *Girard* with the mandate of achieving visible results as fast as possible (unachievable target of finishing the works by summer 1805) even if *Girard* had little experience about such a project and therefore met the fierce opposition of the *Conseil Général des Ponts et Chaussées*. A recent book by Frédéric Graber (2009) analyze precisely such a debate and controversy.

additional *droit d'octroi* completed by other sources within the public budget. The precise repartition of the funding between the *droit d'octroi* and the other sources of funding is not clear on the basis of our sources.

Most of the works had been executed by private *entrepreneurs* chosen through selective procurement, however "charity workers" and war prisoners were also involved in the construction. Indeed a rather handy in-kind grant.

3.2 Canal de l'Ourcq – phase 2 – concession and borrowing : an in-between

The concession approach

The second phase of the Ourcq canal project took place after Napoleon's fall during the Borbonian *Restauration,* in years where the city of Paris had to face harsh financial constraints[12].

In this context, the prefect of Paris *Gaspard de Chabrol* adopted the policy of both slowing down the works rhythm to adapt to the available financial resources and of choosing public private partnerships for the larger investments including the second phase of the *Ourcq* canal.

Indeed, inspired by the English example, the idea of involving private companies in bridging the financial gap for large investments started at that time to seduce many decision makers in Paris. That was the opinion of the *Ponts et Chaussées* commission on the Ourcq canal. According to the 1816 commission report (Conseil Général des Ponts et Chaussées 1816), up to 38 million francs and 10 years were still needed to complete the construction. The commission wanted to avoid the large time and cost overruns of the first phase. On the cost

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[11] Indeed between 1806 and 1815 three different budget were created for the city of Paris : the ordinary budget, the extraordinary budget and the special account for the Ourcq canal. Decision on the two latter budgets were taken by the "*Conseil d'administration*" chaired by the Emperor himself. The Paris City council (*conseil municipal)* was limited to the approval of the ordinary budget only, in fact with no real decision power (Cadoux 1900, 15).

[12] It is useful to remind here some facts about the historical context of those years. During the troubled events of 1814-1815, the city of Paris was occupied twice by foreign occupation armies and had to cover the heavy occupation charges (more than 5 M francs in 1814 and more than 44 M F in 1815) (Massa-Gille 1973). Although the city had been authorised to borrow up to 12 M francs to cover those charges, the cost of money was so high in those years that borrowing was not a practicable solution. Finding additional municipal revenues, which were mainly based on consumption taxes such as the *droit d'octroi*, was not possible either due to the harsh 1816 corn crisis. The city had no other choice than issuing short term bonds – *bons d'échéance*. The reimbursement of these credits was very hard due to the lack of revenues and the city had to issue additional bons d'échéance in order to repay the expired bonds. At some point there were more than 27 M francs of short term bonds issued by the city of Paris in circulation – "the city had practically minted money". The financial constraints which the city of Paris had to face where tight even after the 1817 borrowing of 31 M francs (loan duration of 10 years) (Massa-Gille 1973)

side, the noticed overrun in expropriation compensation-costs due to windfall effect was a particularly sensitive issue. On this base the commission strongly recommended the city to adopt a concession approach[13] selecting a private company to be involved in the funding and execution of the forthcoming phase of the project.

The awarding of the first concession in 1818 - Ourcq and Saint Denis canal

Two companies answered the call for tenders for the completion of the Ourcq and Saint Denis canals and for the execution of the *canal Saint Martin*. However, one of them was excluded because its offer was based on the use of English cast iron, which was unacceptable for a government which was sensible to the lobby of the French iron industry.

Box 2 : The case of the Compagnie des Eaux de Paris (1778-1788)

Concession schemes had already been set up in the past in the French context but for much smaller investments. The case of the *Compagnie des Eaux de Paris* created in 1778 by the *Périer* brothers is a well known example of such a scheme. At that time the "private service" consisting in bringing water "*à l'étage*" (upstairs) was considered a luxury by French authorities whose main concern was to deliver water nearly for free at public fountains. Thus the *Compagnie des Eaux de Paris* was given a 15 years concession for supplying 3000 m^3 of water per day and distributing it both at public fountains and *à l'étage* in apartment buildings. To achieve its objective the company had to invest in steam engines to elevate and deliver the *Seine* water. The company did not last very long: it went bankrupt in 1788 and its assets became property of the royal treasury. Why did this company fail? One possible reason is that the company had the duty of selling and delivering water to public fountains and it was not compulsory for small users to subscribe to the upstairs service which was the only one to be profitable for the company (Cebron de Lisle 1991, 85; Bezançon 1999, 87).

A contract was signed with the *compagnie Vassal et Saint Didier* which was founded in 1818. The company had to finance the completion of the Ourcq and Saint Denis canals and received

[13] The approach was mainly financial as the works had to be executed under public authorities control : the city borrows some capital from a private financial company which gets the money through the emission of shares. The paying off of the capital is leant against the revenues coming from the canal which are given to the company while the interests are covered by annual payments from the city (Gille 1965, 203 quoted in; Massa-Gille 1973, 135). Indeed the Ponts et Chausées engineers wished to keep the control on the works undertaken. As a fact, 19th century canals in France were more frequently realized on a "*Soumission"* agreement basis rather than a full *"concession"*(Nieradzik 2007). The Paris canal case however does not fully fit in the *"concession"* model or in the "*Soumission"* one and is somehow in between. Nevertheless, in this paper we will refer to it as a "concession".

in turn the revenues from the navigation traffic through a 99 years concession plus a 7.5 M francs initial grant to be paid by the government. The Saint Martin canal and the distribution network for the Ourcq water were at first excluded from the concession but the company agreed to submit a similar offer for the *canal Saint Martin* afterwards.

However only 0.5 M francs had to be paid cash to the company while the other 7 M francs would be paid through *bons d'échéances* (time drafts). In fact with such a mechanism the company was both investing in the concession and lending money to the city by accepting to receive the grant later in time. The agreement was approved by the Paris city council the 24th April 1818 and some time later by the parliament to comply with the 1818 law which subjected any borrowing made by cities to an approval by the parliament. A strong debate took place in the parliament on the pros and cons of such an agreement: a penalizing offer obtained through insufficient competition according to the MP Delessert, a very good offer on the contrary according to the *Ponts et Chaussées* director Becquey which pointed out that the Ourcq canal part of the project would provide nearly no revenues at all to the company. According to Becquey the revenues would come only from the Canal Saint Denis and could be estimated in 300 000 francs, corresponding to a 5% rate of return. Finally the parliament authorised the city of Paris to borrow 7 M francs according to the terms of the agreement which are summarised in the table below. The city would pay off the 7 M of *bons d'échéance* with the revenues coming from the additional *droit d'octroi* on wine (refer also to Box 1 for comments on municipal fiscal resources).

Table 3 : 1818 Ourcq concession agreement

Duration of the concession	99 years
Contribution of the city	7.5 M francs grant land purchase and expropriation compensation costs
Starting of the works	Before the 01 January 1819
End of the works	Before the 31 December 1822
"Grant" characteristics	0.5 M francs paid cash 7 M paid through time drafts – *bons d'échéance* issued according to the works rhythm 7.5 % interest rate on the bond part Grace period until the end of the works (payoff to start after the 01/01/1823)

Source : author's elaboration

The awarding of the second concession in 1821 - Canal Saint-Martin

A rather striking peculiarity of the concession awarding in 1818 is the fact that two different tasks were assigned to the company : a) the achievement of works to be financed both through a public grant and through the company equity b) a 7 M francs credit awarded by the company to the city. The law of the 5th of August 1821 asked to modify the awarding mechanism to be used for canals concessions in France. The awarding procedure had to be

split in two separate tenders: a first one for the selection of a company for the concession including the execution of the works, which were technically specified by the public autorities, (competition based on the minimum grant asked), a second one for the selection of a financial partner who would lend money to the city. The purpose of this two-fold approach was to put larger competition in particular in the borrowing conditions to obtain better terms for the city.

Through the first tender the *Compagnie des Canaux de Paris* (former *Compagnie Vassal and Saint Didier)* was awarded the concession for the Saint Martin canal on the basis of a city grant of 5 470 000 francs.

A second competition took place to obtain a 8 M francs nominal credit which had been authorized by the government (400 000 francs of annuity at 5% interest rate). The tender was held at very similar conditions as the emission of state bonds. Twenty one companies answered to the bid based on the lowest emission discount over the nominal value. The city obtained 7 924 000 francs against a nominal capital value of 8 M francs[14] (refer also to Table 6). These funds were supposed to cover both the payment of the grant to the *Compagnie des Canaux de Paris* and the land purchase and expropriation compensation costs (which in fact grew up quite fast above the estimated amounts).

3.3 Canal de l'Ourcq and canal Saint Martin : from concession to public ownership

We have already pointed out that a harsh debate took place in the parliament in 1818 on the pros and cons of the concession approach. The debate on the best institutional solution for the Paris canals management came back in the 1860's when the city decided to realize the *Boulevard Richard Lenoir* above the Saint Martin Canal in order to stop splitting up in two parts this area of the city. The public interest was then in conflict with the company which argued that the roofing of the canal was prejudicial to her interest. The city ended up buying back the concession of the Saint Martin Canal to the company in 1861 (Humblot 1885).

[14] The poorest offer was at 93.55 (*Lefebvre)* while the winning one was at 99.05 (*G. Odier).* This was a low and interesting emission discount since the same year French state bonds were emitted at discount value of 89.55. The funds had to be paid to the city through in 8 payments between July 1822 and April 1824. The payback time was of 27.5 years. The effective interest rate is of 5.5 % (Gallais-Hamonno 2007, 267).

Another similar conflict took place during the important drought period of 1875. According to the 1818 agreement the company had to deliver to the city 80 000 m3 of water per day. During the drought the city wanted to allow people to draw additional water from the canal while the company had rented the canal bank to private workshops and small factories which needed the hydraulic force of the flow. Once again the public interest was in conflict with the company's profitability. Again, the city decided to reclaim the ownership of the Ourcq and Saint Denis canals.

These two early terminations of the contract implied the payment of an annual installment by the city to the company until 1922 as a compensation for the lost revenues. The compensation annuities agreed was of 180 000 francs for the *Saint Martin* Canal (plus an indemnity *una tantum* of 1 338 800 francs) and of 540 000 francs for the *Ourcq* and *Saint Denis* canals (Humblot 1885).

In his report of 1885, Mr Humblot, which was the *Ingénieur en chef des Ponts et Chaussées* in charge of the *service des canaux et de l'assainissement de Paris,* appears to be very critical on the choice of the concession which had been made. He shows some figures in order to demonstrate the excessive-profit which in his opinion had been made by the *Compagnie des Canaux de Paris* and argues that surely the city of Paris could have found a loan in 1823 to a much better interest rate with the advantage of avoiding the conflicts and transaction costs of 1861 and 1876 which had been very high according to his view.

Table 4 : Cost estimation for the Ourcq canal, comparison of various data sources

	Estimations in French Francs, nominal amounts	Belgrand	Martin Saint-Leon et Cadoux	Humblot
1	Ourcq ante 1816	13 578 177		
2	Ourcq post 1816	9 973 150		
3	Saint Denis	2 992000		
4	Saint Martin	8 347 240		
5	Gare Arsenal	3 569 759		
6	Total post 1816 (2+3+4+5)	24 882 149	31 391 753	
7	Total expenses (1+2+3+4+5)	38 460 326	49 448 000	
8	Gross total expenses 1818 agreement (2+3)	12 965 150		
9	Gross total expenses 1821 agreement (4+5)	11 916 999		
10	grant 1818 agreement	7 500 000		
11	grant 1821 agreement	5 470 000		
12	Net expenses supported by the company 1818 (8-10)	5 465 150		3 922 650
13	Net expenses supported by the company 1821 (9-11)	6 446 999		2 831 310

Source : author's elaboration, data from Belgrand (1873), Martin Saint-Léon (1843) and (1885), quoted by Cebron de L'isle (1991, 139–140)

On the contrary G. Massa-Gille (1973) points out the harsh financial constraints of the city of Paris in 1818 and 1821 when the agreements were made. The city had nearly "no credit" at all in the financial circles at that time. And if the estimation of 300 000 francs of expected

revenues from the Saint Denis canal was correct, the profitability that the company would get on its net expenses would hardly exceed 5%. Not only it is not the purpose of our work to judge the historical choices which had been made but there are also so different and incoherent figures available on the costs of the three canals (refer to Table 4); so a large uncertainty surrounds them and makes an objective analysis almost impossible.

4 Water distribution network for the city: the temptation of the concession approach 1806-1853

As already mentioned, although the revenues would come from the navigation tariffs, the main purpose of the Ourcq canal system was to bring additional water for the needs of the city (*les eaux nouvelles* as opposed to *les eaux anciennes* which were at that time mainly the Seine water pumped through steam engines, some wells and the *Medicis Arcueil aqueduct*). Indeed the idea behind the project was to bring larger quantities of water to the city for supplying public needs such as street washing and fire fighting, as in the *water in quantity paradigm* (Barraqué 2003b; Barraqué, Britto, and Formiga Johnsson).

With the decree of the 4th of September 1807 the ownership and management of all the water supply in Paris was transferred from the state to the municipal administration (*Prefet de la Seine*) both concerning the *eaux nouvelles* and the *eaux anciennes*. However the state administration kept exerting a strong supervision on it through the *Directeur Général des Ponts et Chaussées* and the *Ministre de l'intérieur.* Indeed during the *Empire*, the emperor exerted a very close control over the municipal administration and water supply was still considered an emperor's gift which would contribute to the city's splendour and to Napoleon's glory (Cebron de Lisle 1991).

Even if the Ourcq's water already reached the *fontaine des Innocents* on August 15th 1809, the city had to wait some more time to get a proper water distribution network. It is well shown in Table 5 that the realization of the water supply network was slow. Indeed, the network completed by 1832 was still largely insufficient to deliver the whole 80 000 m3 per day that the Ourcq canal was supposed to supply.

Three ambitious projects (*Projet Girard, Projet Mallet, Projet Genieys)* were drafted for the Ourcq water distribution network. Quite soon however suspicions arose on the real quality of the Ourcq water in parallel with the concept of realizing two separate distribution networks : one for the residential drinking water delivered *à l'etage* (Seine water) and one for the public fountains and other needs (Ourcq water) (Cebron de Lisle 1991).

The various projects estimated the financial needs between 31 M francs (*Projet Mallet)* and 18.7 M francs (*Projet Genieys*). Due to the huge amounts of money needed, the city was tempted for a long time to award a concession on water distribution to a private company which could obtain more easily the financial resources needed. However the concession had also many opponents and the debate on whether it was the right approach or not was fierce.

The memory of the failure of the *Compagnie des Eaux de Paris* in 1788 (refer to Box 2) was an argument against the concession. Furthermore, awarding such a concession was not an easy task due to the conflicting interest between the city (which wanted the company to deliver for free at public fountains) and the company (whose revenues and profitability would depend on a sufficient number of private subscriptions). The financial constraints of the city, the hesitation between the various projects and the debate on the opportunity of a concession approach slowed down the extension of the water network ; until 1830 works were undertaken only with minor ordinary funds taken on the annual city's budget surplus.

Table 5 : Water and sewer system lengths (1806-1930)

Year	Water network length (km)	Sewer system length[15] (km)
1806		24
1823		33
1832	39 (Ourcq network)	40
1840	312	110
1849		121
1855	364 (in 1854)	163
1860	465	230
1874	1374	
1880	1527	619
1885	1979	833
1890	2125	899
1895	2289	987
1900	2533	1090
1905	2632	1173
1910	2745	1204
1913	2796	1225
1915	2800	1230
1920	2823	1233
1930	2867	1303

Source : Authors elaboration, inspired from various sources (Cebron de Lisle 1991, 247, 424, 559; Lemarchand 1914, 164; Lemarchand 1923, 274) and from Annuaire Statistique de la Ville de Paris, various years

Even if the Paris water distribution concession failed to be awarded in the end, it is rather interesting to point out and analyze the main attempts to initiate it made by the city of Paris in the first half of the 19th century.

[15] Except sewer building connections

A negotiation with the company of the English brothers *Lees* started in 1814 and was in its final step in 1817 when the government rejected the principle of a settling through a simple mutual agreement *intuitu personae* and required a transparent and competitive bid (Mallet 1830). In order to get some benchmarking on how to draft the technical specifications of such a tender Mr Mallet led a mission in 1824 to England and particularly to London where private companies already had concessions on water distribution (Chatzis 2010).

A competitive bid was then launched in 1829 according to the following terms : i) a 99 years concession of all the existing Paris water infrastructure currently managed by the city with an exclusive right of installing and exploiting underground water distribution pipes, ii)obligation to complete and maintain the infrastructures needed to deliver the Ourcq's water to the public fountains, iii)execution and maintenance of the infrastructure needed to distribute Seine water, iii)a free delivery to the city of a fixed amount of Seine water to supply some public fountains, iv) a price cap on water subscription fees for domestic use and v) payment of a annual royalty equivalent to one tenth of the gross revenue from sold water. No offers were received for that bid. The main cause of the failure was probably the obligation made to the company to complete and maintain the unprofitable Ourcq water network to supply the public fountains on which no revenues could be expected (Cebron de Lisle 1991).

With the new Paris administration, led by prefect Rambuteau, further attempts were made to award a concession to a private company. New specifications were drafted and approved by the municipal council in 1834. Learning from the 1830 tender failure, the city had chosen to limit the concession to the distribution of Seine water on which a private company could expect to get some revenues, leaving the completion of the Ourcq public fountains network to the city's initiative. However the *Conseil Général des Ponts et Chaussées* never approved these specifications and suggested in 1836 to concede the water distribution service to the Lees company through a simple mutual agreement. It was asked to the Lees company a 2 M francs deposit to guarantee their offer. They preferred to withdraw their offer (Beaumont-Maillet 1991). Once again the attempt to award a concession failed.

The concession temptation however came back once more in 1852-1853 under the *Second empire.* The city launched again a call for tender for a concession of the water service. Five offers were received including one of the *Compagnie Générale des Eaux* (CGE) whose creation had been led by the very influent Comte Siméon. Napoleon III had nearly chosen to award the concession to the CGE when the new prefect of Paris, Baron Haussmann managed

to convince the Emperor to stop that process in order to maintain the city's control on water supply.

In fact Haussmann's opposition to the concession scheme was based on strategic technical choices rather than on any judgment on the best institutional framework. Assisted by Eugène Belgrand, the chief engineer he had appointed, Haussmann had the intuition which would be later confirmed by Koch and Pasteur's scientific discoveries, that all the water containing organic matter in dissolution (such as in the Seine and Ourcq) should not be considered drinkable. Haussmann and Belgrand were then convinced of the necessity of bringing distant and clean water to the city from far away sources and were therefore opposed to the mainstream idea of pumping more water from the Seine as the CGE or another company would have done if they had been awarded the concession.

In the meantime in the suburbs, outside Paris administrative boundaries, various concessions had been awarded since the 1820's to various private companies delivering Seine water elevated through steam pumps. By 1859, the CGE had bought all the previous existing companies and was responsible of the water service in 26 municipalities in the Paris suburbs through concession contracts. In June 1859 however, the annexation of many suburbs municipalities to the capital city took place (Figure 1). A solution had to be found concerning CGE's rights in the formerly independent areas of the new Paris. The 50 years legal agreement of 1860 between the city of Paris and CGE consisted both in a "municipalization and a (partial) privatization" (Bocquet, Chatzis, and Sander 2008) : a) the Paris municipal service acquired the entire water infrastructure of the formerly autonomous municipalities from CGE[16] ; b) CGE was not awarded a full concession but only a *régie interessée* contract according to which the company was responsible for commercializing water, handling relations with subscribers, and billing and collecting payments on behalf of the city. CGE kept however the full management of various water services outside Paris new administrative boundaries[17] (Cebron de Lisle 1991, 387).

[16] The city's agreed to pay a 50 years long annual royalty of 1 600 000 F to CGE until 1910 (Morizet 1932, 329).

[17] The CGE activities in the suburbs expanded even more after the 1867 amendment to the 1860 contract : the City of Paris withdrew from all the water supply contracts with neighbouring suburbs and left CGE totally free to expand its activity as a *concessionaire* ouside Paris administrative boundaries (Bocquet, Chatzis, and Sander 2008).

5 The increasing trend to finance investments through debt

After a quick retrospective glimpse on the first half of the 19th century (paragraph 5.1), this section is focused on investments undertaken in the 1852-1925 time frame. Paragraph 5.2 sketch the new borrowing policy. Paragraph 5.3 analyzes deeply financing tools used during Haussmann's urban transformative of Paris. Paragraphs 5.4 and 5.5 summarize the major water and sanitation infrastructure undertaken in those 75 years. Paragraph 5.6 details the financing policy for such an ambitious investment plan. Last paragraph (5.7) gives some concluding remarks on the key role played by long term debt.

5.1 A cautious attitude until 1850

During the *Empire* and the *Restauration* the city was generally reluctant to borrow (only 5 loans were issued before 1850 as shown in Table 6) and rather adopted the cautious attitude of financing investments either on the surplus of the ordinary budget or through the concession approach by giving up future revenues to the concessionaire.

Table 6 : Loan issued by the city of Paris in the 19th century

Year of issue	Capital		Interest rate		Annual lots KF	Duration	Payement duration	Main scopes
	collected MF	nominal MF	coupon %	effective %				
1817	31	33	6.0	9.86	240 to 888.88	12	19 terms over 18 months	
1815-1822	2.57	4.24	5.0	10.48	-		1 term	
1832	40	40	4.0	7.91	112	20	5 terms over 5 months	Consolidation
1849	27.63	25	5.0	4.53	198	10	unknown	Budgetary deficits of the 1846 to 1850 years
1852	61.39	50	5.0	3.71	336	19	unknown	*1er réseau* - Public works (*Les Halles* and *rue de Rivoli*)
1855	60	75	3.0	5.07	300	42	7 terms over 18 months	*1er réseau* - Public works, *rue de Rivoli. bd Sébastopol. av. Victoria*
1857	50	57.3	4.0	5.10	125	31.5	5 terms over 16 months	*Caisse de la Boulangerie* (bakery basket fund)
1860	136.62	143.8	3.0	4.0	300	37	9 terms over 27 months	*2ème réseau* - Public works, including *Dhuis adduction* and water and sewer systems
1865	270	300	4.0	5.09	1 140	63.5	8 terms over 4 years	Publ. works (annexation expenses), incl. *Vanne adduction* and water and sewer systems
1869	260	300.5	3.0	4.47	1 000	40	4 terms over 1 year	Payback to the *Crédit foncier* of the *bons de délégation*

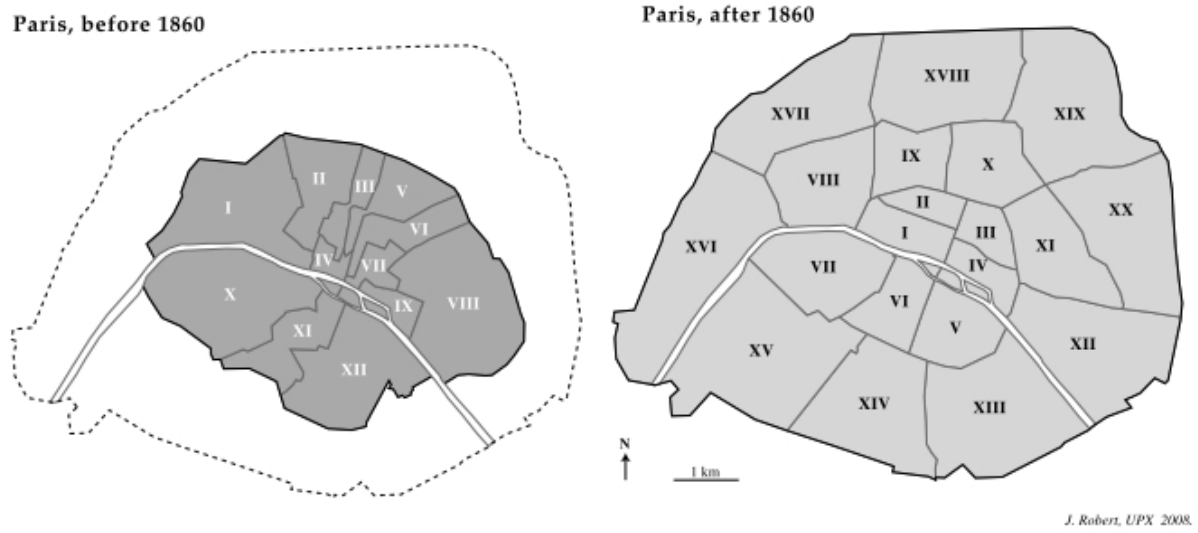
Source: author's adaptation from Gallais-Hamonno (2007, Electronic Annex II). In grey loans on which water infrastructures were partly financed.

As early as in the 1820's a debate took place between the city decision makers (Massa-Gille 1973): on one side the "cautious approach" suggested both to slow down the works and to find some surplus in the city's budget to fund them on. On the contrary the "gambling approach" implied to borrow in order to accelerate the rhythm of works which would contribute to increase the city's revenues and allow to payback the loan. Let us keep in mind that the borrowed amounts represented only 10% of the total revenues of the city during the *Restauration* and only 7.5% between 1821 and 1830 showing a cautious borrowing policy (Massa-Gille 1973).

5.2 The turning point in the city's borrowing policy

The approach changed with the new *régime* led by Napoleon III who wished to quickly undertake urban renovation, complete infrastructures and obtain visible results in order to build a new Paris and consolidate his power. A tension arose on the borrowing issue between prefect Jean-Jacques Berger and minister Persigny which was in favour of borrowing large amounts of money in order to accelerate the rhythm of the works. Berger was reluctant to borrow and had instead a cautious financial strategy which consisted in making up the provisional city's budget in order to show larger expenses and lower revenues and to secretly expect to get an important surplus at the end of the year. In fact this had been also the strategy of the previous prefect *Rambuteau* in order to get more funds for Paris approved by the parliament where the MPs coming from other geographical regions were often reluctant to allocate funds to the capital city.

Figure 1 : Administrative boundaries of Paris before / after 1860



Source : Bocquet, Chatzis and Sander (2008)

Against his own opinion, Berger had to accept the undertaking of some large urban renovation works (new streets next to the Louvre, creation of the *Boulevard de Strasbourg*) financed through a 50 M francs loan (subscribed in 1852 by the city) whose payoff was still covered by the additional *droit d'octroi* on wine which had been extended until 1870. Persigny however wanted to borrow even more. In his opinion a new loan could be issued and guaranteed by the annual surplus of the city's budget which was significant in those years thanks to the upturn in the economy and also to the cautious financial policy of the previous years. In fact, Persigny's strategy aimed at using the funds borrowed to buy land which would be sold later to a building contractor with a capital gain for the city (due to the urban renovation of the area) which would allow to payback the loan and invest in another similar operation (we will give more details on these land value capture financing schemes in the next paragraph). That was too much for Berger who "did not accept to ruin the city and to burden with debt the future generation"[18]. Berger resigned and was replaced by Haussmann with the clear mandate of modernizing the city of Paris from a "congested medieval city into a dynamic metropolis"[19] . In Haussmann's view a modern city needed improved circulations not only of people and commodities but also air, water and even money. Haussmann initiated a urban renovation of Paris based on new enlarged *boulevards* including a modern water supply network and sewers.

5.3 Haussmann : reshaping the city by all means (1852 -1869)

The transformation of Paris

The huge investments undertaken by Haussmann between 1852 and 1869 aimed at shaping a brand new city with large *boulevards* and new modern buildings in the framework of a "centrally directed public investment"[20] strategy based on the Saint-Simonian ideas of the "productive expenses"[21]. To comply with Napoleon III's will, Haussmann gave an exaggerated rhythm to Paris urban renovation works not hesitating to borrow more and more in a sort of self-powered vicious circle.

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[18] Cebron de Lisle (1991)
[19] Gandy (1999, 27)
[20] Gandy (1999, 28)
[21] The *théorie des dépenses productives* can be summarized by the following sentence by Saint-Simon (1760-1825) quoted by Marchand (2011) « in a stable régime, investments become productive ». Saint-Simonian ideas "played a significant role in the development of new political and economic ideas, which reflected the growing influence of industrialists and scientists in nineteenth-century France […] and proved highly influential within the French engineering profession." (Gandy 1999, footnote 31)

A great amount of literature already exists on Haussmann's transformation of Paris and going deeply into that issue is far beyond this paper's scope. Thus, we will only give a few figures to remember the extent of the changes which took place in that historical phase. Between 1852 and 1868 more than half of Paris buildings were demolished (18 000 buildings demolished on a total of 30 770 buildings in Paris at that time). 60 % of Paris's surface was transformed over 17 years (Marchand 2011). Undertaken investments over 17 years add up to a total of 2.5 billions francs[22] (Marchand 2011) and are summarized in the table below.

Table 7 : Urban investments in Haussmann's mandate (1853-1869

	Amount (francs, nominal value)
Urban renovation operations	1 400 000 000
Other investments associated to urban renovation operations : -Public buildings -water and sanitation systems -tree-lined walkways	700 000 000 (284 000 000) (153 000 000) (177 000 000)
Concession compensation costs *-Compagnie Générale des Eaux* *-canal Saint Martin and Saint Maur* *-abattoirs* *-compagnie des petites voitures*	90 000 000
Debt service burden associated to investments previously undertaken	145 000 000
Debt service burden associated to Haussmann's investments	200 000 000
Total	2 535 000 000

Source : author's elaboration, based on Morizet (1932, 282) and Haussmann(2000, II – 337–340 original numbers)

Although water and sanitation investments were essential for the development of Paris, their 153 M francs amounts are small if compared to the total 2.5 billion francs. An analysis of water and sanitation investments in those years would be incomplete without looking at the global picture of the massive urban transformation which took place.

Infrastructure financing scheme

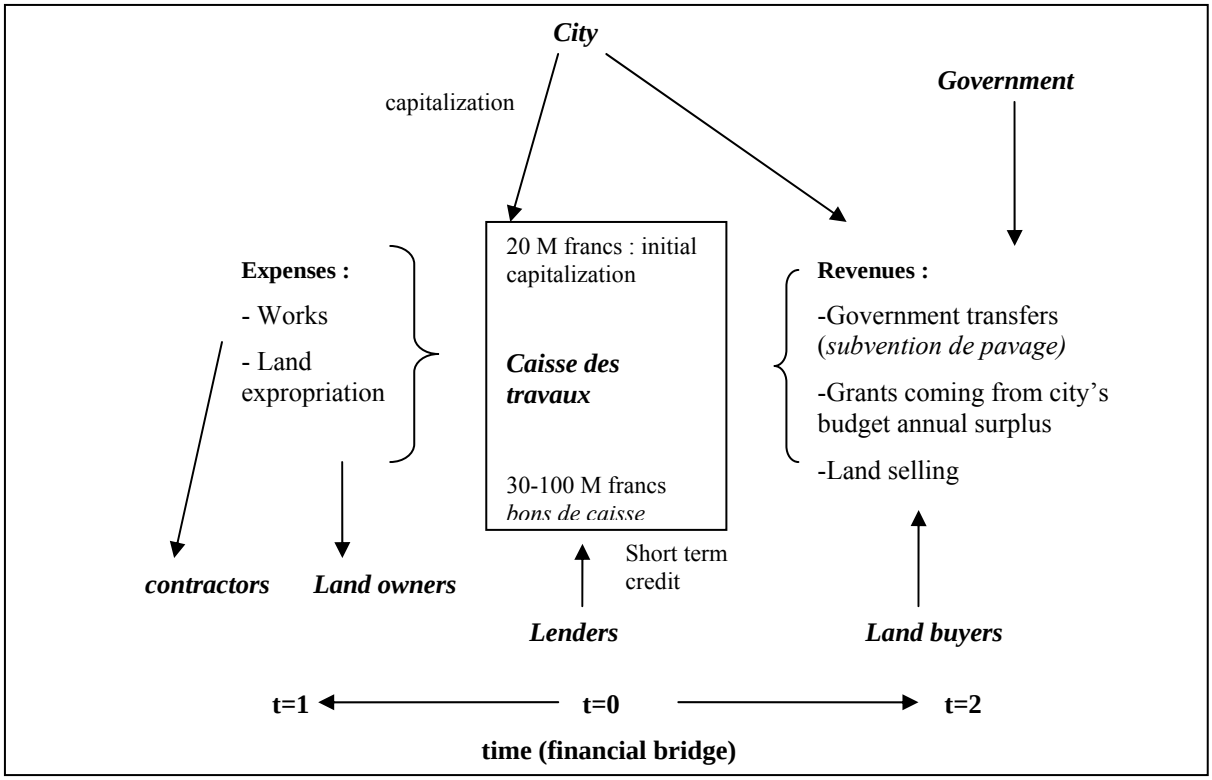
Three infrastructure financing schemes were adopted by Haussmann (Massa-Gille 1973). We will shortly describe them in this paragraph before going back to their implication in water infrastructures financing in paragraph 5.6.

The first financing tool consisted in traditional borrowing through issuing municipal bonds (as the ones listed in Table 6 above). The second one, the *Caisse des travaux* (established through the decree of November 14th 1858), was an integrated financing scheme for urban renovation, which consisted in a revolving short term basket fund which was initially funded by the city with 20 M francs. The idea of this fund (shown in the below scheme) was to bridge the

[22] That amount represented roughly the total annual budget of the French state at that time (2 billion francs) (Marchand 2011).

expenses to be paid at the beginning of an urban renovation operation (land purchase and expropriation, works) and the funds to be obtained later (government transfers[23], fiscal resources from the city's budget surplus and revenues from land selling). Resources of the *Caisse des travaux* came from the initial capitalization made by the city and through the emission of short term credit certificates (*bons de caisse).* Cautiously the parliament put a cap of 100 M francs[24] on the amount which could be borrowed through the *Caisse des travaux.*

Figure 2 : The *Caisse des travaux* institutional scheme



Source : author's elaboration

Despite the large borrowing amounts which were issued mainly through municipal bonds (Table 6), funds were still short to cover all the works at the rhythm planned by Haussmann. A third financing scheme, similar to Persigny's initial idea, started – *les bons de delegations* : in that scheme the city gave a concession to a contractor for expropriating and acquiring some areas, demolishing the old buildings and streets, realizing the new *Boulevard*, giving it back to the city and finally selling either the land or the new buildings (refer to the Figure 3 below). The city would pay a grant (partially covered by the government through the *subvention de pavage*) to the contractor linked with the value of the renovated street. In fact the grant would

[23] The so called "*subvention de pavage".*
[24] Initially the approved cap was of only 30 M francs but under political pressure it was later extended to 100 M francs (Massa-Gille 1973, 252)

be paid cash to the contractor by a bank (taken a fee on it) on the basis of the city's guarantee. The contractor would anticipate the funds both for the land purchase expropriation costs and for the works while it would get its profitability from the property value capital gain at the end of the whole operation. The city had found a way to borrow both from the contractor (the land purchase/expropriation and works costs) and from the bank (the credit given in advance on the grant to be paid). The contractor's funds could come from his equity but were very often borrowed from banks which would be the major lenders. In fact very often the banks would enter in the capital of the contractor's company in order to get a share of the expected capital gain. The banks themselves, and particularly the *Crédit Foncier*[25] which had been established by the government in 1852, were collecting money through their own bond emission.

Expropriation rules, procurement and risk allocation

In all the administrative documents of that time the urban renovation operations undertaken by Haussmann are classified in 3 groups ("*les trois réseaux*") according to the importance of the government's grant in the financing scheme. Some data on the three urban transformation phases are summarized in the table below. The first works, *le premier réseau* launched at the beginning of the *Second Empire* was strongly subsidized by the government since the parliament did not dare to oppose to the emperor. Later MP's from rural areas progressively curbed down all attempts to subsidize the capital city (Morizet 1932, 202). As a consequence, the second phase of works was less subsidized and the third one, *le troisième réseau,* was not subsidized at all by the government. As the works went on, not only subsidies decreased but also opposition to municipal borrowing rose progressively. Indeed while the 1855 and 1860 loans were easily voted by the Parliament, approval for the 1865 loan was obtained narrowly (Moncan and Heurteux 2002; quoted by Marchand 2011). Regarding the1869 consolidation loan with the *Crédit Foncier,* opposition to its approval was so fierce than it implied Haussmann's power loss and lead sometimes later to his fall (Morizet 1932, 299). Works within the *troisième réseau* started under Haussmann's mandate, lasted mainly until 1880 but were not fully completed until 1905.

Within the *Premier réseau*, financed by the 1852 and 1855 loan (Table 6) works were mainly undertaken in-house (*en régie*) by the municipality with only minor works contracted out to

[25] Indeed, the *Crédit Foncier* played a key role in the financing of Paris municipal infrastructure both in the framework of Haussmann's *Bons de Délégation* and afterwards since it was one of the few financial institutions authorized to lend money to French municipalities.

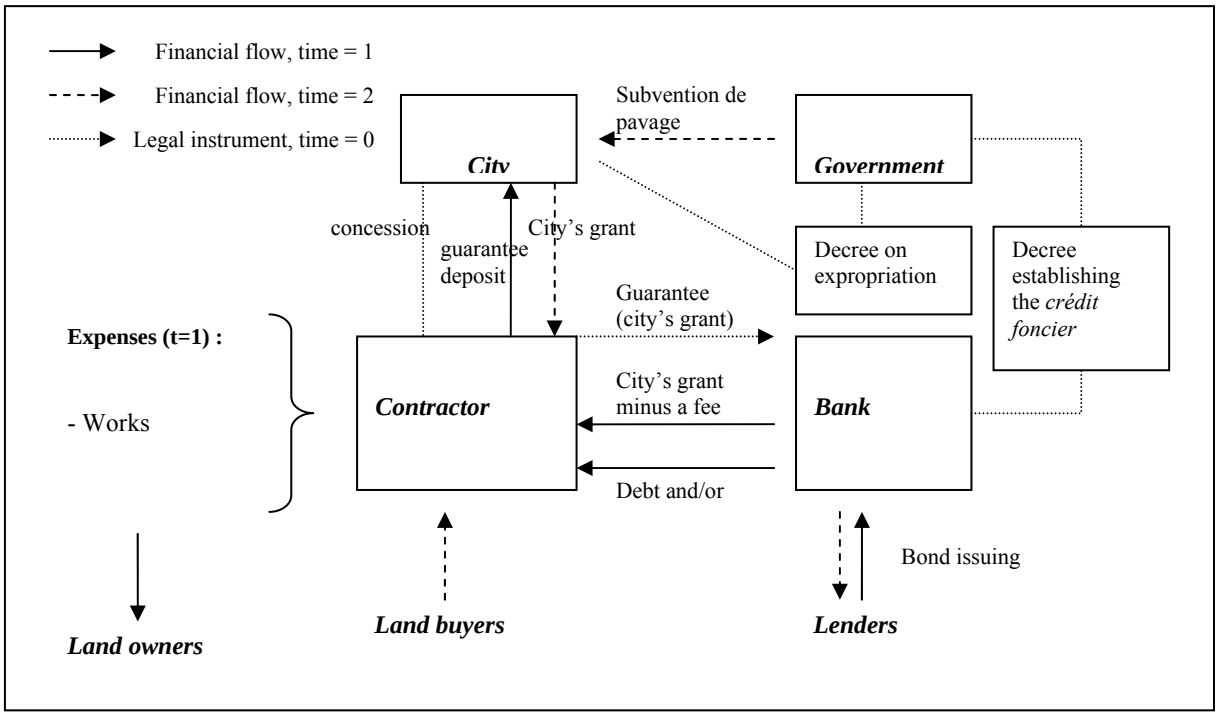
private companies[26]. On the contrary urban renovation operations within the *deuxième réseau* and even more within the *troisième réseau* were mostly undertaken by selected private contractors.

Table 8 : Main data on the three phases of Paris urban transformation (1852-1880)

Operation	Time frame	Main purpose	Length (km)	Costs (MF)	Financing tools
1er réseau	1851-1857 Already sketched in 1793	*Rue de Rivoli* *Bd St Michel – Bd Sebastopol*	9.5	272	121 MF on the 1852 and 1855 loans. Governmental subsidy of roughly 93 MF[27]
2ème réseau	1858-1868	Connecting the city centre with the outlying districts	27	410	50 MF government subsidy 1865 loan
3ème réseau	Main phase until 1880. Last operation in 1905 (*Bd Raspail)*	New streets incl. in the new districts after the annexation.	64.5	300	No governmental subsidy

Source : author's elaboration, inspired from Marchand (2011)

Figure 3 : the *Bons de délégations* institutional scheme



Source : author's elaboration

Within these urban renovation operations, entire buildings, streets and areas were renovated including refurbished streets and modern networks such as water, sanitation and gas street

[26] *Sociéte Ardoin et Ricardo* involved in the *Boulevard de Strasbourg ; Société Immobilière* involved in a part of the *Rue de Rivoli* and in the *Boulevard Malesherbes* operation (Morizet 1932, 287).
[27] Morizet (1932, 202)

lighting (Morizet 1932, 287). Costs of these public infrastructure were initially covered by the contractor and paid back later by selling the land or the buildings with a higher market value.

We will jointly refer to the *Caisse des travaux* and *Bons de delegations* as "Integrated Urban Development" mechanisms. A key legal instrument allowing the implementation of these two schemes was the 1852 decree on expropriation rules (*decret loi du 26 mars 1852*) which had been issued by the government. The previous law of 1841 already authorized the expropriation of buildings and land on the layout of the new streets. Nevertheless the 1852 decree was much more powerful[28] since, on the grounds of the fight against insalubrity, it authorized to expropriate also all the properties impacted even marginally by the planned works[29]. Doing so, the city could expropriate a much larger area and capture a greater part of the capital gain on land value when selling it at the end of the renovation operation. However, after 1858, land owners consistently appealed against the expropriation acts and their positions prevailed most of the time in the judgements of the *Conseil d'Etat.* After 1858 properties could be expropriated less easily and had instead to be bought at increasingly high market value. Even when the expropriation went on, according to the *Conseil d'Etat* jurisprudence, the city had to give back to the previous owners any part of the properties un-impacted by the works (Marchand 2011). As a consequence a larger part of added property value escaped from the city's control. Furthermore, due to a 1858 decree (December 27th 1858), in the framework of an expropriation, the city had to pay an indemnity not only to the owners but to the tenant too. Obtaining the land for the urban renovation operation became increasingly costly.

Depending on the financing tool chosen and on the entity responsible of the works and expropriation various allocations of risks were taking place (Table 9 below). In fact each operation consisted in both an urban renovation and a borrowing with respectively an operational and financial risk associated. On one hand the operational risk (cost overrun on works, complexity and costs overrun in the expropriation procedure) was taken either by the city (in-house responsibility of the expropriation and works) or by the contractor. On the other hand the financial risk was taken by the lenders which were municipal bond's subscribers,

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[28] André Morizet defines the 1852 decree as *un instrument précieux* (Morizet 1932, 182)

[29] *Decret Loi du 26 mars 1852* : "*Dans tout projet d'expropriation pour l'élargissement, le redressement ou la formation des rues de Paris, l'Administration aura la faculté de comprendre la totalité des immeubles atteints, lorsqu'elle jugera que les parties restantes ne sont pas d'une étendue ou d'une forme qui permette d'y élever des constructions salubres*", quoted by Faure (2004, 12)

bons de caisse's subscribers or banks in the case of the *bons de delegations*. In this latter case the ultimate lenders were however the individual bank's bonds's subscribers which were taking the risk associated to the bank's financial soundness.

As the expropriation procedures were eased with the adoption of the 1852 decree, the operational risk perceived by private contractors decreased and they engaged themselves more frequently in those urban renovation operations (Morizet 1932, 287). After 1858 the operational risk increased back again as the expropriation went less smoothly. As a consequence urban renovation's costs went up and their rhythm kept slowing down also due to the city's growing financial constraints which lead to Haussmann's decline and fall in 1870 (Marchand 2011).

Table 9 : Risk allocation according to the financing scheme

Financing tool	Entity responsible of the works and expropriation	Operational risk	Financial risk
Municipal bond	Contractor	Contractor	Lenders (municipal bond suscribers)
	City (in-house)	City	
Caisse travaux	Contractor	Contractor	Lenders (*bons de caisse* subscribers)
	City (in-house)	City	
Bons de délégation	Contractor	Contractor	Bank (equity or debt) + subscribers of bank's bonds

Source : author's elaboration

The slippery grounds of borrowing

The integrated urban development financial schemes adopted by Haussmann, especially the *Bons de delegation,* were very controversial since in many opponents' view they consisted in hidden loans adopted to bypass the borrowing cap imposed by the parliament. Suspicions on the legality of these schemes progressively grew up in the 1860's (Morizet 1932, 288) but Haussmann's was at first protected in high places. Meanwhile, financial needs to cover urban operation costs were constantly increasing. Furthermore, as most of the *Bons de delegations* were in the hand of the *Crédit Foncier*, its financial soundness was in precarious equilibrium. A debt consolidation agreement between the city and the *Credit Foncier* was needed to extend the debt's maturity: it required an official approval. The debate was harsh as shown in the famous *pamphlet "Les Comptes fantastiques d'Haussmann"* by Jules Ferry (1868) accusing Haussmann to put abusively the city into a massive debt which shall weight on the next generations. Although the consolidation loan was approved in 1969 (Table 6), in turn

Haussmann lost most of his power and *prestige* and fell a few months later on January the 5th 1870.

To summarize, in Haussmann's era the city of Paris borrowed massively to finance its urban development (including water and sanitation infrastructures). Not only large loans were subscribed through municipal bonds but two other financing schemes based on land value capture were experienced to bypass the borrowing cap imposed by the parliament. The next two paragraphs will sketch the main investments brought to completion concerning water and sanitation while paragraph 5.6 will detail which financing tools used to undertake those investments.

5.4 Investments in water and sanitation (1853 -1878)

A very significant part of Paris's water infrastructure has been realized between 1853 and 1925. The main investments concerned:

a) the strategic water supply elements (mainly aqueducts and reservoirs as summarized in Table 11) aimed at bringing clean water to the city and storing it,

b) water pumping stations withdrawing surface water from rivers (partially summarized in Table 12 and Table 13 : investments in surface water adduction (1876-1889)Table 13),

c) Waste water treatment plant through land farming (*épandage*) (Table 16 and Table 15)

d) and last but not least water distribution and networks (Table 5 and Table 14).

In this paragraph and in the following one we will give a historical overview on these investments. The 1853-1925 can be framed in two time periods : a first phase goes from 1853 to 1880 until Belgrand's death during Paris urban transformation years ; after Belgrand a second phase opens and ends symbolically in 1925 with the realization of the *Voulzie* which is the last long-distance aqueduct built in Paris.

The Haussmann and Belgrand's era

Haussmann was very concerned with the water supply issue[30] and presented with his water specialist , the engineer Eugène Belgrand, three *Mémoires* to the city council on that topic in 1854, in 1858 and in 1860 (Haussmann et al. 2000). Planned investments in water were already huge, they became even larger after the annexation of the new districts to extend

[30] Referring to Haussmann's view on Paris water André Morizet reports "*Abreuver Paris ! Cette preoccupation qui l'etreindra sans cesse l'apparente à Napoleon"*(Morizet 1932, 184, 282)

water and sewerage to the new areas (Figure 1). Indeed the population of Paris increased from 1 174 346 inhabitants in 1856 to 1 696 141 in 1861, after the annexation (Bocquet, Chatzis, and Sander 2008) and the surface of Paris more than doubled from 34.02 to 78.02 km^2 (Morizet 1932, 278). Global investments amounts in water and sanitation during Haussmann's mandate (1853-1869) add up to 150 M francs[31] as summarized in the table below.

Major water infrastructure were completed under Haussmann's and Belgrand lead : the water supply and sewer systems' length was extended massively as the new streets and *Boulevards* were completed (eg. 1374 km of water supply network in 1876 compared to the 364 km in 1854). In those years the choice to install two water supply networks[32] within the sewers[33] was made. One network was initially dedicated to the "public service" that is the public fountains and street washing (Ourcq water) and one other to the "private service", that is domestic connections (Seine water and later water from the gravity aqueducts)[34].

Table 10 : Investments amounts (French francs, nominal value) in the sewerage and water systems (1851-1873)

Years	Water system (including both network and strategic supply elements)	Sewer network only	
	New investments	New investments	Maintenance
1851-1855	3 539 063	2 549 024	481 455
1855-1860	7 770 653	8 085 496	1 223 332
1861-1865	35 482 878	16 999 389	4 520 586
1866-1870	43 317 742	17 478 301	7 069 793
1871-1873	14 985 873	407 289	5 151 339
Sub-total	105 096 209	45 519 499	18 446 505
Total		150 615 708	

Source: author's elaboration, data from Cebron de Lisle (1991, 429)

[31] This amount is consistent with the figures given in Table 7 even if the time framing is not exactly the same.

[32] Both water networks are still operated in Paris today, one for drinking water (from gravity aqueducts and Seine water after treatment) and one for non drinking water (Ourcq and Seine water lightly treated). Domestic users are connected only to the the drinking water network. The Paris city council has made the decision in March 2012 to keep in operation the non drinking water network and invest in its maintenance.

[33] The order of magnitude in Table 5 appears to be correct since sewer system length is roughly half of the water network one.

[34] The size of the sewers was over-engineered in order to install within them the two water networks (and even other kind of networks in more recent years) according to the concept of the one single *galerie technique.* Probably the initial cost per km of sewer was higher than in a classical sewer but *ex-post* such a choice appear from the cost point of view to be smart as it is much easier and cheaper to maintain water networks installed in accessible sewer than underground ones. On the other hand the working conditions inside the sewers are poor and might have a negative impact on the workers health. According to this view the city of Paris is nowadays "prisoner" of a technical choice made more than a century ago when acceptable health and working conditions standard where much poorer than nowadays. If the data were available it would be interesting to undertake a cost-benefit analysis of the (positive and negative) externalities on the long run of such a technical choice.

Two main sewers (*collecteur general d'Asnières* and *collecteur de la Bièvre*) were also completed between 1857 and 1868 for a total cost of 3.75 MF and 6.5 MF respectively. Major investments in water production capacity were brought to completion too, such as the *Dhuis* and *Vanne* long distance aqueduct (refer to the table Table 11). The latter was only initiated under Haussmann's mandate and was completed only in 1976.

Even if Haussmann and Belgrand were in favor of spring water and long-distance aqueducts (water quantity paradigm) rather than surface water, they invested in various surface water pumping plants (*Austerlitz*, *Saint-Maur, Trilbardou* and *Isles* – refer to Table 12) in order to satisfy the huge and urgent Paris's water needs. Surface water was seen as the only solution able to fill the water gap in the short run but it was seen as a temporary solution since it was planned in the mid and long run to deliver only spring water to all districts.

Table 11 : Main investments in water supply devices (1862-1900),

Operation name	Included infrastructures	Costs (Francs)	Loan	Comments
Dhuis adduction 1862-1865		27 560 000		
	Dhuis aqueduct	18 000 000		131 km
	Storage unit Menilmontant et Belleville	4 560 000		123000 m^3
	Main water distribution network	5 000 000		
Vanne adduction 1867-1876		48 782 000	Partially on the 1865 loan + 18 M on the 1872 special loan	
	Vanne aqueduct	37 230 000		173 km
	Storage unit Montrouge	6 000 000		204000 m^3
	Main water distribution network	2 200 000		
	Additional expenses	3 352 000[35]		
Vigne and Avre adductions 1891-1893	Vigne and Avre aqueducts	35 000 000	35 M 1886 loan[36]	102 km
	Storage unit Saint Cloud			286 000 m^3
Loing and Lunain adductions 1897-1900 + 1911 – 1922		28 000 000 (Cebron de L'isle) 70 000 000[37]	23 M on the 1894 loan	73 km Pumping station at Sorques
Voulzie 1922 -1925		53 000 000	53 MF on 1921 loan	45 km

Source : author's elaboration, data coming from (Cebron de Lisle 1991; Beaumont-Maillet 1991)

Clearly Haussmann and Belgrand upgraded significantly Paris's water and sanitation services through an ambitious investment plan which proved to be long lasting as a great lot of infrastructures built in that phase are still in operation nowadays. Although a huge progress had been made at the end of the 1870's compared to the initial 1852 situation, Paris's water

[35] Lemarchand (1923, 205)
[36] Lemarchand (1923, 161)
[37] Lemarchand (1923, 179), including the second phase of works 1911 - 1922

and sanitation infrastructure was still incomplete and investments needs were huge as we will detail in the next paragraph.

5.5 Investments in water and sanitation (1878 -1925)

After Haussmann's fall, Belgrand kept his key role at the *Direction des Eaux* for a few years. What was the global picture of the Paris's water and sanitation service at his death in 1878?

On the water supply side, in the previous years the city had mainly invested in spring water aqueducts (*Dhuis* and *Vanne*) and water distribution systems as we detailed in the previous paragraph (Table 5 and Table 11). Notwithstanding, in the 1870's the city was also pumping water from the Seine and the Marne rivers through various pumping stations (Table 12). Some of them had been obtained through the 1860 agreement and where previously operated by CGE while others had been built during Haussmann's mandate.

In 1878 theoretical daily production capacity was somewhere between 300 000 and 370 000 m^3 depending on various factors while the planned needs were estimated in 480 000 m^3 (Cebron de Lisle 1991, 468). The daily additional water need was around 180 000 m^3. Furthermore there were still harsh inequalities in water quality and quantity delivered between the wealthy city centre and the working-class inhabited outlying districts[38]. It was urgent to increase daily water production and to complete the two water distribution systems (domestic water and public water network).

Table 12 : Pumping stations in operation in 1878 within Paris water service

River	Location	Technical aspects	comments
Seine	Port-à-l'anglais (Ivry)	12 steam engines adding up to a total of 2130 horsepower	ex CGE
	Maison Alfort		ex CGE
	Austerlitz		
	Chaillot		
	Auteuil		ex CGE
	Saint-Ouen		ex CGE
Marne	Saint-Maur	8 hydraulic engines + 2 steam engines	
Marne - Ourcq	Isle-lès-Meuldeuse	4 engines	
	Tribardou		
Vanne		4 small engines	
Within the distribution network	Montmartre		
	Menilmontant		
	Ourcq		

Source : author's elaboration, data coming from (Cebron de Lisle 1991, 490)

[38] In those years the a mortality rate in the X,XI,XII,XIX and XX *arrondissements* was twice or three times the average one in Paris (Jaquemet 1979, 522)

Even nowadays sanitation is often seen as the poor relation of water supply which often focuses all efforts. In Paris too, until 1840, the priority had been given to investments in water supply rather than sanitation. Views changed when the urban renovation of Paris started and investing in sewers which would incorporate water supply systems was considered an essential part of all urban renovation operations. Although the impressive amount of 619 km of sewers had been completed by 1879, large investments were still needed to improve further the meshing of the sewer system.

Furthermore, three major sewers[39] (*collecteur géneral d'Asnières, collecteur de Bièvre, collecteur du Nord)* had been realized on the left and right bank of the river collecting waste water in the various areas and discharging it further downstream. Those sewers however were not a solution to the huge problem of the pollution of the *Seine* River downstream of Paris. A first small-scale experiment of waste water treatment by land farming was launched by the city after 1865 in the outskirts of Paris (*Clichy* and *Genevilliers*). By 1878 it had showed some first results but needed to be extended on a larger scale.

Table 13 : investments in surface water adduction (1876-1889)

River	Location	Technical aspects	Amount	comments
Seine	Ivry	85 000 m^3/day	17 M Francs	Including two additional reservoirs of 5 000 m^3 (Gentilly) and 25 000 m^3 (Villejuif
	Javel	25 000 m^3/day		
	Bercy	50 000 m^3/day		
Marne	Saint-Maur	20 000 m^3/day		Additional steam engine
Various	Some minor investments			

Source : author's elaboration, data coming from Cebron de Lisle (1991)

A new investment plan (1880-1925)

To face such a poor situation both in water supply and sanitation, huge investments were made between 1880 and the 1920's, shaping Paris modern water infrastructure as many of them are still in use nowadays. Symbolically this investment phase ends in 1925 with the completion of the *Voulzie* adduction operation which was the last long-distance spring water aqueduct built in Paris. The major investments brought to completion in this phase included:

A) Water supply

a) new spring water aqueducts which are detailed in Table 11 : *Vigne* and *Avre ; Loing* and *Lunain ;* and finally the *Voulzie* in 1924,

[39] The total of the three sewers give 30 km of total length and 4155 hectare of sewer collection basin area (Cebron de Lisle 1991, 424).

b) new investments in surface water production units totalizing 17 M francs between 1876 and 1889 (Table 13),

c) the extension of the water distribution networks from 1527 to 2867 km for a total invested amount of more than 20 M Francs (Table 14),

d) the progressive use of disinfection and water treatment to purify drinking water (after 1911),

B) Sanitation (refer also to Box 3)

e) the extension of the sewer system from 619 to 1303 km (in 1913) for a total invested amount of more than 70 M Francs (Table 14),

f) new land farming waste water land farming units downstream of Paris able to "treat" a fraction of Paris daily water consumption (Table 15 and Table 16) for a total invested amount of more than 50 M Francs.

How such an ambitious investment plan was financed? This is the central question we will analyze in the next paragraph.

Table 14 : Investments amounts (French francs, nominal value) in the sewer and water supply networks (1878-1922), author's elaboration

Years	Water supply network investments	Sewer network investments[40]	Comments
1878-1884		10 048 930	
1885-1889	12 00 000	2 700 000	
1890 - 1894	1 665 367	7 782 400	
1895 -1899	2 985 000	19 053 630	Law on the *tout-à-l'égout* in 1894
1900-1904	1 720 000	16 615 000	
1905-1909	1 096 617	6 506 534	In those years investments were also due to the subway realization
1910-1914	638 315	19 035 000	
1915-1919	1 397 197	undetermined	
1920-1922	762 546	undetermined	
Sub-total	22 265 042	71 692 564	
Total	93 957 606		

Source: author's elaboration, data from Lemarchand (third colum inspired from Lemarchand 1923, 288 , second column summarizing various pages from Lemarchand 1914, 134)

[40] All amounts in this table give only round figures as an order of magnitude of the undertaken investments. Particularly on the sewer investments the original source does not appear fully consistent in all the figures which may still contain errors.

Table 15 : Main investment funds approved by the city's council for the waste water treatment through land farming until 1900, funds approved by the city's council

Approval date	Amount	Comments
Prior to 1875	4 335 000	*Genneviliers* pilot phase
1892	10 500 000	*Clichy* pumping unit, land purchase in *Garenne* and *Fromainville*, depressed sewer
1893	1 047 000	Land purchase
1894	11 300 000	*Herblay* extension of the *Achères* unit, *Méry sur Oise* branch, engines for the *Clichy* plant, *Argenteuil* pipe
1897	4 520 000	Pipe and distribution network in *Pierrelaye* and *Carrières sous Poissy*
1900a	19 600 000	Extension of the *Colombes* pumping station, extension of the main *Asnières* sewer, additional branches towards *Verneuil*
1900b	5 300 000	*Pierrelaye unit and drains*
total	**52 267 000**	

Source : author's elaboration, data from Lemarchand (1914)

Table 16 : Volumes of waste water treated through land farming downstream of Paris (1872 – 1900)

	1872	1882	1892	1902	1912
Daily water consumption Paris (m^3)	300 000	318 782	538 000	662 840	856 635
Daily waste water "treated" (m^3)	4 838	52 058	91 017	620 668	556 846
Annual waste water « treated » (m^3)	1 765 870	19 001 170	33 221 205	226 543 820	203 248 790
Land farming surface (km^2)	0.57	5.39	7.76	53.0	51.12
Pumping engine power (horse power)	150	700	1 100	7 555	8 790
Land farming unit in operation	Gennevilliers			Gennevilliers, Achères, Méry-Pierrelaye, Carrière-Triel	

Source : author's elaboration, data from Lemarchand (1914)

5.6 Financing tools for water and sanitation infrastructure (1853 – 1925)

In the previous paragraph we sketched the major investment steps in water and sanitation. This section will show how the large expenses in Paris's water and sanitation infrastructure have been financed in those 70 years of progressive upgrading. We will follow a chronological order focusing our attention on the Haussmann's years first and on the next fifty years afterwards.

The Haussmann's era (1853-1869)

The major urban transformation which took place under Haussmann's mandate was implemented using various and innovative financing tools (described in paragraph 5.3).

Water and sanitation investments undertaken in those years can be classified in two main different kinds of infrastructure: a) on one hand the strategic water supply elements (mainly aqueducts and reservoirs as summarised in Table 11) aimed at bringing clean water to the city and storing it, b) on the other hand the distribution and sewer systems. Two different

financing tools were adopted by Haussmann's city administration for these two categories of infrastructures.

On one hand the strategic water supply elements were financed through various municipal multipurpose loans (grey items in Table 6) which would finance various sectors (public works, water, sanitation, schools).

On the contrary water distribution and sewer systems have been financed through bond emission only to a small extent. They were partly financed through ordinary public funds coming from the city's budget (surplus)[41]. Annual expenses increased massively after 1857 when annual allocation on the ordinary budget dedicated to water investments were increased from 0.5 to 1 M francs[42] (Cebron de Lisle 1991, 429). But there is still some money missing to cover the large costs of these networks.

It appears that networks (water and sanitation) were largely built in the context of integrated urban renovation operations which transformed Paris in Haussmann's years and afterwards. Network development was only a single element of more complex and large operations through which entire buildings, streets and areas were renovated. Network costs were then absorbed in the global cost of these operations which were financed through complex and controversial schemes such as the *Caisse de travaux* and the *Bons de delegation* which we described in the paragraph 5.3[43].

In both cases[44] of "Integrated Urban Development Mechanisms", the capital gain expected on the property value (land value capture) was the key concept behind. The network development phase was then partly financed by these schemes based on land value capture.

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[41] Obviously it is much easier to finance on ordinary budget surplus the network extension rather than a new aqueduct since the network extension rhythm can be adapted easily to the existing budget while half an aqueduct is not that useful.

[42] After 1870 the sewer system extension slowed down suddenly because money was given in priority to the Vanne aqueduct operation (Cebron de Lisle 1991, 429). Both Table 10 and Table 5 confirm this fact. The latter also shows an increase in sewerage extension after 1894 due to the new law on the "*tout à l'égout"* through which no other disposal method for waste water was legal except the discharge in the sewer system (Cebron de Lisle 1991, 595).

[43] "New investments" in water and sewerage " were paid through the *Caisse des travaux"*, in particular in the new areas of Paris after the annexation (Belgrand 1873, 327–329, tome 4, quoted by ; Cebron de Lisle 1991, 429).

[44] The main idea was that the city would give a concession to a contractor for expropriating and acquiring some areas, demolishing the old buildings and streets, realizing the new *Boulevard*, including the water and sewer system, giving it back to the city and finally selling either the land or the new buildings (Gallais-Hamonno 2007; Massa-Gille 1973).

On the contrary the large lump-sum investments needed to build the "strategic water supply devices" were mainly financed through municipal bonds.

Investment financing policy under the *Troisième république*

We have already described in paragraph 5.3 how prefect Haussmann lost progressively his power in 1969 due to the complex investment mechanism implemented. Those mechanisms considered by his opponents as a hidden and illegal debt which would seriously limit the city's capability to invest in the forthcoming decades.

Thus, after Haussmann's years the city's council was very reluctant to borrow in spite of the huge city's investments needs in various sectors including water and sanitation. Nevertheless, the city had no other choice than issuing three more loans in 1869[45] (consolidation loan with the *Crédit Foncier*), in 1871 (war debt to the Prussian government) and in 1872 (Vanne adduction). The 1872 loan was urgently needed to complete the *Vanne* adduction operation which had been stopped due to the 1870 war. A 19.5 MF loan was subscribed with the *Crédit Industriel et Commercial* and specifically dedicated to the *Vanne* operation even if the financial conditions were not favourable[46].

The 1875 and 1876 loans had to be issued too in order to consolidate the debt and to partially finance urban renovation operations which were part of the *Troisième réseau* previously planned. Those operations were still under completion, at least until 1890, under the responsibility of the same Mr Alphand who had been the director of the Municipal Public Works department under Haussmann. The controversial mechanisms of the *Caisse des Travaux* and the *Bons de delegation* were not anymore in use after Hausmann's fall. Nevertheless, Integrated Urban Development mechanisms based on "hidden borrowing" and land value capture still continued to be used by Alphand's department to finance urban renovation operations including water and sewer systems (Morizet 1932, 337).

After the 1871, 1872, 1875 and 1876 loans, seen as legacy of the past, no other loans were issued by the city until 1886. Indeed, the majority of the City's council was opposed to any deficit finance investment plan and was convinced instead that investments should be financed on ordinary budget's surplus as much as possible. This was a huge constraint on the

[45] The 1869 loan was issued still under Haussmann's mandate.
[46] In fact the city redeemed that loan a few years later with the funds collected with the 1875 loan which had been issued at better financial conditions.

development of modern infrastructure in a city with a massive demographic growth rate of 14% (between 1876 and 1881) in those years (Jaquemet 1979).

Due to the City's council ostracism to loan issuing, until 1887, the only source of funding available consisted in annual funds taken on the surplus of the municipal's budget. As a consequence, most of the 17M investments (Table 13) in surface water plants[47] brought to completion between 1876 to 1889 have been financed on ordinary funds (Cebron de Lisle 1991, 493).

Progressively, as the time distance with Haussmann's years increased, the city's council became more favorable to the idea of issuing new loans. In fact, in many sectors the needs were so urgent that investments could hardly be postponed. The borrowing constraint was particularly heavy to bear for the water and sanitation sector in terms of poor sanitary conditions[48] in a city that had reached 2 269 023 inhabitants in 1881 (Jaquemet 1979). Indeed, WSS infrastructures available were largely insufficient to prevent epidemics of cholera (major epidemics events in 1884 and 1892) and typhoid fever which were particularly recurrent in such a context of large demographic growth. In addition, those were the years of great knowledge progress in microbiology, hygiene and medicine which investigated and progressively demonstrated the key link between microbes and diseases and the causality between the access to clean water and sanitation and epidemics control[49].

Increasing concern for sanitary conditions (particularly in the outlying districts) and the great cholera epidemic of 1881 played a role in making the member of the city's council to allocate 60 M Francs over the total 250 M Francs of the 1886 loan[50] to water and sanitation infrastructure (Cebron de Lisle 1991, 482). The amount of 60 M was far below what the water and sanitation department had asked but still allowed to finance various operations mainly concerning water supply. Once again sanitation had been considered the poor relation of water supply.

Some funds (27 MF) were allocated to water and sanitation, including the *Achères* land-farming project, on the 1892-94 loan (200MF). However it was only in 1894 that sanitation

[47] Particularly *Ivry* water plant and the extension of *Saint-Maur* water plant.
[48] Refer to the "snapshot" of the 1878 situation given in the previous paragraph.
[49] For example, the causality between drinking water and cholera had been described by Dr Marey at the *Académie de Médecine* in 1884 (Jaquemet 1979, 525).
[50] The main scopes of the 1886 loan were investments in schools (Jules Ferry law on schools in 1881-82) and public works. WSS Allocations :*Vigne* and *Avre* water adduction : 35 MF ; water plants and networks : 15 MF ; Sanitation : 8 MF ; Canals : 2 MF

rose to the top of the polical agenda both at City's council and parliament level. The *Tout-à-l'égout* was made compulsory, the city was authorised to levy an administrative tax on wastewater collected (refer also to paragraph 6.1) and the *Achères* land farming project was approved. A 117.5 MF loan was issued in 1896[51] to finance the Loing and Lunain adduction (50 MF), sewers (35.2 MF) and wastewater treatment in Achères (30.8 MF). The priority was not only to invest in sanitation but also to increase water supply (possibly from spring sources) as water consumption was expected to increase due to the generalization of the *tout-à-l'égout*. The availability of borrowed funds after 1886, 1892-94 and 1896 explains the increasing amount of investments made in the years afterwards, especially in sanitation, extending the sewer system and increasing the irrigated areas in the land farming process.

Box 3 : The *tout-à-l'égout* and land-farming debate

Although the rhythm of investments in sanitation was not as high as needed, the debate in the 1880's was very rich both on the *tout-à-l'égout* issue and on the use of land-farming to treat wastewater downstream of Paris (Jaquemet 1979). Opposition[52] to the *tout-à-l'égout* system[53] was coming mainly from landlords and cesspool emptiers. The first were opposed because the *tout-à-l'égout* implied a domestic water connection with higher consumption of water and higher costs. Cesspool emptiers too were obviously against the *tout-à-l'égout* which would seriously threat their business model. A second debate was taking place on whether it was appropriate to use landfarming (*champs d'épandage)* to treat waste water downstream of Paris (*Genevilliers, Achères, Saint-Germain)* in order to lighten the pollution's burden on the *Seine* river and to use waste water as an productive input for agriculture. The planned project implied to use lands which were property of the State, an approval by the Government was required for the city to obtain the right to use those areas. Meanwhile a fierce opposition was coming from the inhabitants and local authorities of the concerned areas. But opposition to such a project was also coming from some politicians and members of the scientific circle in favour of an alternative project consisting in a canal from Paris to the sea (Jaquemet 1979).

The waste water was delivered both in areas partially purchased by the city of Paris and delegated to farmers and in fields fully owned by private farmers (17.97 km2 of *Domaines* versus 33.33 km2 of *Cultures libres* respectively in 1909[54]). Although waste water treatment through land-farming irrigation mitigated the Seine's pollution at first, in fact the allowed absorption volumes[55] were chronically insufficient as the collected waste

[51] It was issued in 1896 jointly with an additional consolidation loan with the Credit Foncier.

[52] Even the French scientific circle was opposed to that solution at first (Jaquemet 1979).

[53] The *tout-à-l'égout* means feces collection through the main sewer while in Paris feces were still mainly collected through cesspools (*fosses d'aisance*) and sanitary tubes (*tinettes filtrantes)*.

[54] Figures from Bellanger (2010, 112)

[55] The April 4th 1889 law authorized to discharge a maximum volume of 40 000 m^3 per hectare of irrigated surface and per year (Bellanger, Pineau, and SIAAP 2010, 111).

water volumes were growing faster than the irrigated surfaces. Absorption capacities started to deacrease after 1902 (law on maximal absorption capacity) and even more after 1906 as the agriculture practices decreased in Genevilliers due to the industrialization and urbanization process (Bellanger, Pineau, and SIAAP 2010, 110–112). In addition to that, using waste water for irrigation in agriculture was not such a smooth process as thought initially. Farmers planned their water demand according to the crop seasonal demand (higher demand in dry season, lower demand in humid season) in order to maximise their crop production while the water offer from the city was related to sewer water collected volumes (higher offer in rain season, lower in dry season). Increasing conflicts arose since the city's engineers considered agriculture in terms of water absorption capacity while in the farmers's view it was a crop production value's maximisation issue (Bellanger, Pineau, and SIAAP 2010, 110). The decline of waste water treatment through land farming has started; however the shift to biological lagooning technology (*épandage biologique)* would not be implemented until the 1920's investment plan and the realization of the *Achères I* waste water treatment plant in 1942.

After the water and sanitation loans phase (1886 to 1896), between 1898 and 1905 large loans were issued by the city to finance the gas network and the *Metropolitain* (subway). Those loans did not directly finance water and sanitation investments. However executing the works for the subway implied large expenses to move the water distribution and sewer networks which were financed with special funds coming from the subway loans[56]. This partially explains the investments amounts in networks (Table 14) even if the sewer and water supply networks were roughly completed by 1900-1905 having already a quite stable length of 2632 km (water) and 1173 km (sewer) (Table 5).

Two additional loans financing water and sanitation were issued in 1908 and 1910. The 1908 31 MF loan, subscribed with the *Credit Foncier,* was issued specifically to finance urgent works on water and sanitation (see table below).

Table 17 : 1908 loan's funds allocation

1908 loan's funds allocation	**Amounts (MF)**
Upgrading of the drinking water service through new drinking water treatment units	5.3
Upgrading of the "public" (raw) water system – Extension of the *Austerlitz* pumping plant and size-doubling of the *Villejuif* reservoir	5.4
Water distribution networks and works due to the subway construction	6.8
Waste water treatment - (new engines in *Colombes* and *Clichy* + extension in *Achères*)	7
Other expenses, including *Avre* adduction compensatory damages	5.5
Financial costs, studies and other expenses	1
Total	**31**

Source : author's elaboration, data from the June 29th 1907 Law (République Française 1912)

[56] Evidence of this fact is given by the *Compte administrative* of 1910 page 846 – 860. It is also confirmed by (Lemarchand 1914; 1923) .

The 1910 loan (the so called *Emprunt des grands travaux)* was planned to be issued in various phases of 235 MF each, totalizing 900 MF. However only the first issuing operation took place and only 17 MF were allocated to the water and sanitation department in front of 130 MF planned investments which were supposed to be financed step by step on the various issuing phases of the loan[57].

After World War I, a large loan of 1800 MF was issued in 1921. Funds from the loan were partially allocated to water and sanitation investments on which funds from the 1910 loan had been initially allocated but not obtained in the end (107.7 MF). Allocations[58] included the *Voulzie* adduction operation (roughly 53 M Francs) which is the last long distance spring water adduction operation realized in Paris and symbolically closes the major investment phase in water and sanitation services. The scientific knowledge progress in microbiology and sanitary engineering had already started around 1910 to experiment water treatment and disinfection techniques including ozone disinfection[59]. The Paris water services were progressively closing the water quantity and water systems paradigm" while discovering the "water treatment and water quality paradigm" (Barraqué 2003b).

5.7 The key role of long term debt

Most of Paris's water infrastructures were shaped in the 1853-1925 years. In a first phase, within Paris's urban transformation, three financing tools were used : funds taken on the city's ordinary budget surplus, integrated urban development mechanisms and municipal loans. Lump-sum and costly investments such as long-distance aqueducts were financed through long-term municipal loans. On the contrary time-spread investments such as water and sanitation networks were largely realized in the framework of Paris's urban transformation and financed through integrated urban development mechanisms. After the completion of

[57] The planned 125 MF investment included : 21.8 MF on surface water pumping stations in order to increase pressure in the nework, 50 MF on the *Voulzie* spring water adduction, 5.5 MF on sewers ; 13 MF on main sewers and 18 MF on waste water treatment. On the 17 MF allocated, 5.5 MF were used on surface water pumping (pressure increase), 7.1 MF on sewers. Source : *Note à l'appui des comptes de dépense de 1912,* Paris, Direction administrative des travaux de Paris

[58] Allocations : Urgent extraordinary maintenance needs for water, sanitation and canals (14.7 MF) ; 33 MF of already undertaken works (including 20 MF on sanitation) ; 60 MF for water investments (including 53 MF) for the Voulzie adduction operation. (Denais 1921)

[59] A competition had been held for the best disinfection technique to be tested in a pilot project within the Saint Maur water treatment plant. The 1908 loan allocated funds to water treatment and disinfections. Filtration basins were already in operations by 1910 on the Ivry water plant. References : *Note à l'appui des comptes de dépense de 1912,* Paris, Direction administrative des travaux de Paris. In 1911 water disinfection starts to be implemented on an industrial basis and after 1914 all surface water delivered to domestic users (in addition to spring water) has been previously filtered (Lemarchand 1923, 876).

Paris urban transformation in 1890, integrated urban development mechanisms played a minor role in water and sanitation investments and the great majority of water and sanitation infrastructure were financed on municipal loans.

Municipal debt appears to be the key economic instrument implemented to channel savings into public infrastructure generating growth. Indeed, in the second half of the 19th century savings were high in France and still largely unproductive[60]. Both Paris's municipal bonds and the *Crédit Foncier* bonds allowing to finance the "*Bons de délégation*" (Figure 3) were attractive investments.

Most of the time the city publicly issued its own municipal bonds but there have also been some cases of loans with bank intermediation, mostly with the *Crédit Foncier.* Indeed, in the case of bank intermediation, the city was allowed by the parliament to subscribe loans only with the *Crédit Foncier,* the *Caisse des depots* and the *Caisse Nationale des Retraites pour la Vieillesse*[61].

In fact, the Parliament's control on city's debt was very tight in those years as not only a law was required to approve the loan but also the funds' allocation was submitted to the central state approval[62] and a "*déclaration d'utilité publique*" (eminent domain declaration) was required for most works.

The municipal loans were mainly multipurpose ones allocated to various sectors of the city's administration. Allocations decisions were made by the city's council and approved by the Government. Most of the time, water and sanitation financing needs were curbed down in order to give more funds to other sectors[63] which were considered to have priority. Only a few loans were specifically issued to finance water infrastructure (in 1872 and 1908) and justified on the high degree of "urgency" of the investments.

The City's fiscal revenues were given as loan collateral in most of the loans we detailed. Indeed loan's approval by the Parliament was based on the principle of using additional tax

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[60] Marchand (2011) and Gandy (1999)

[61] Example : *Loi 2 mai 1921 autorisant le département de la Seine à souscrire un emprunt de 500 millions euros sur 50 ans ; Loi 10 juin 1921 autorisant emprunt 1800 millions pour la Ville de Paris*

[62] « *Les travaux prévus ne pourront être entrepris qu'autant que les modalités d'execution techniques auront étés approuvées par le Ministre de l'Intérieur après avis du conseil supérieur de l'hygiène publique de France.* » (République Française 1912, 278)

[63] For example it was the case for the 1892-94 loan or for the 1910 loan.

revenue[64] as a collateral. Since the water and sanitation financing needs were often left unsatisfied in the city's council funds allocation decisions, various attempts were made in the 1880's to convince the city's council to approve a specific loan dedicated to water investment and having as a collateral the estimated future revenues of the water and sanitation service. All those attempts did not succeed in obtaining the City's council approval (Cebron de Lisle 1991, 480). It was only with the 1894 *tout-à-l'égout law* that a 117.5 MF loan having the new sanitation levy as a collateral was approved by the City's Council and by the Parliament. Somehow the sanitation levy, based on the property value, was still considered more similar to a fiscal revenue than to a tariff. It was only in 1980 that water revenues were partially used as collateral to issue a loan[65] and indeed the debt's service to payback that loan was accounted for within the water department accounting chapters while it was not the case for all the other loans as we will show further in paragraph 6.2.

Most of the issued loans had a very long maturity[66]. According to Marchand (2011) savers in those years were trusting long term investments of that kind thanks to the gold standard comforting effect. In retrospect view however, those savers lost most of their money as the great inflation of the 1910-1930 years curbed down severely in real terms the profitability of their investments. Indeed, we will further analyse the key effect of inflation in paragraph 6.3 while next section will sketch what were the cost-sharing effects of these mechanisms in the long run. Who was the end-payer *in fine* in those schemes?

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[64] The June 10th 1921 law authorised for example the city to raise 50 additional centimes on the tax base : "*50 centimes aditionnels) aditionnels au principal des 4 contributions directes"*

[65] A special fund was created to collect up to 3MF coming from water revenues and allowing to cover the loan's amortization. That special fund was supposed to be the collateral for the three first years while the general budget would be used as a collateral afterwards. (République Française 1912, 278)

[66] Another peculiarity of most loans was that they allowed a time spread credit *tranche* drawing which could best follow the works' rhythm. This is daily practice nowadays but it was an innovative practice in those years.

Table 18 : Loans issued by the city of Paris 1869 – 1930, in grey loans on which water infrastructures were partly financed.

Year of issue	Capital		Interest rate		Annual lots KF	Duration	Payment duration	Main scopes (WSS details)
	collected MF	nominal MF	coupon %	effective %				
1871	350	517.32	3.0	5.36	1 500	75	4 terms over 1 year	War contribution and consolidation loan
1872	19.5	19.5	6.0	5.99	no	5 to 20	4 terms over 3 months	*Vanne* water adduction operation 18 MF
1875	220	250	4.0	5.0	900	75	3 terms over 2 years	Consolidation and public works
1876	129	120	4.0	4.84	500	73	3 terms over 21 months	Public works and buildings incl. *Rue Reaumur*
1886	249.75 WSS : 60	277.5	3.0	3.88	1 000	75	1 term	Public works (incl WSS) *Vigne* and *Avre* : 35 MF Water (plants and networks) : 15 MF Sanitation : 8 MF Canals : 2 MF
1892-94	200 WSS : 27	231	2.5	3.63	800	79	7 terms over 5 years	Public works, WSS and schools WSS : 27 including *Achères* waste water land-farming
1894-96	- WSS: 117.5	161.5	2.5	3.45	646	77	1 term	Public works schools and WSS[67] + payback and consolidation with *Crédit Foncier*
1898	300.1	344.8	2.0	3.02	1 200	74		Conversion 1886 loan + subway
1899	169	206	2.0	3.12	600	78	6 terms over 3 years	subway
1904	170	193	2.5	4.08	700	75	9 terms over 3.5 years	Subway Pas en morizet
1905	100	105	2.75	3.66	400	35	4 terms over 1 an	Gas
1906	105		3.55			50	Loan with the *Crédit Foncier*	Gas, pompes funèbres and schools
1908	4.58		3.60			18	Loan with the *Crédit Foncier*	
1908	31	31	3.75	3.783		53	Loan with the *Crédit Foncier*	Water and sanitation only Refer to Table 17
1910a	45	46	2.75	3.51	210.8	69	1 term	subway
1910b	235[68]	241	3.0	3.59	1 810	80	8 terms over 3 years	Public works 17MF on water and sanitation
1912a		100	3.75			66	Loan with the *Crédit Foncier*	Subway
1912b		205	3	3.73		39		Gas
1913		20	4.2			78	Loan with the CNRV[69]	Social Housing *(Habitations bons marché)*
1919		1500	5			61		War debt consolidation
1920		400	6.75[70]			50		
1921		1800	5.75			61		Muncipal budget deficit (1820-1821), social housing, public works incl. WSS (107.7 MF)[71]

Sources : author's elaboration, data from *Annuaire Statistique de la Ville de Paris* 1925, Morizet (1932, 332) and Gallais-Hamonno (2007, Electronic Annex II).

[67] *Loing* and *Lunain :* 50MF ; Sewers : 35.2 MF; Wastewater treatment (Achères) : 30.8 MF

[68] It is the so called *emprunt des grands travaux* – initially 900 MF loan but only first draft issued (235 MF).

[69] *Caisse Nationale des Retraites pour la Vieilliesse*

[70] 6.75 interest rate until 1938, then 6.70

[71] Water : 60MF (incl.53 M for the *Voulzie* adduction) ; Sanitation : 33MF ; urgent extraordinary maintenance14.7 MF (Denais 1921)

6 Long-run cost allocation and intergenerational effect

Once analysed how an investment has been financed, as done in the previous sections, it is a key issue to discuss the long run (final) cost allocation which might be very different from the short run one. In other words it is essential to distinguish the (short run) financial solution from the (long run) economic equilibrium. This section is focused on such an issue.

For example let us think of an aqueduct which in the short run has been financed through municipal bonds. Depending on various institutional choices the loan's burden might weigh down different stakeholders: the local or national tax payers if the loan repayment comes from fiscal resources (municipal or national), the users if the revenue from the service repays the loan or a mix of both categories. If we adopt the OECD 3T's methodology[72] (OECD 2009), which one of the 3T's did pay back the investment *in fine* ? The answer is not straightforward since the water, sanitation and canals departments were part of the municipal administration and accounted within the municipal general budget. To tackle such a question paragraph 6.1 will focus on the way water and sanitation revenues were collected, paragraph 6.2 will analyse WSS's financial flows in the 1893-1920 time frame, paragraph 6.3 will deal with the role played by inflation while paragraph 6.4 will further discuss the long run cost allocation.

6.1 Billing water and taxing sanitation

Under Hausmmann's mandate water infrastructure was seen as a potential source of revenues for the city. It made sense then to capitalize these revenues through a loan which they would payback. Haussmann and his municipal administration had already an industrial and commercial vision of the water service. That vision is quite similar to the "municipal capitalism" described by Millward (2000, 324) as the main driver in favour of public ownership[73]. According to such a vision, the *Compagnie Générale des Eaux* (CGE) was entrusted through the 1860 agreement[74] of *régie intéressée* with the task of collecting the water bills[75] (refer to section 4). Through such an agreement water service revenues were

[72] 3T's : Tariff, Transfer, Taxes

[73] According to Millward (2000), municipal enterprise in England in the second half of the 19th century is much more driven by the will to increase municipal revenues through municipal enterprise's rates rather than a municipal socialism ideology which in fact appeared later in the early decades of the 20th century.

[74] Un amendment to the 1860 agreement was signed in 1869. A new agreement was signed on February 11th 1911 at the expiry of the first one. A third agreement was signed on February 1930.

[75] The municipality kept under its own responsibility (*régie directe)* the commercial relationship with water users within the public administration.

secured and the commercial risk taken by CGE. The municipality could focus its attention on operations and especially on investments and works.

In 1854 only one building over five in Paris had a domestic water connection. Twenty years later one building over two was connected as the number of domestic water connections increased from 6229 to 39 104 (Chatzis 2006). At first two kinds of subscriptions were available: the *robinet libre* and the *à la jauge* subscription. The first implied an unlimited quantity of water and was offered only for Ourcq water. The latter consisted in a pipe gauged allowing only a fixed discharge. It implied having a water storage capacity within the building. It was used for the *Seine* water connections (and also later for the spring water connections) in the purpose of better controlling consumption (Cebron de Lisle 1991, 191). It is only after 1880 that subscriptions with water meters[76] started to be set up in order both to disincentive excessive water consumption and to increase water revenues through a more faithful metering and billing (Chatzis 2006). After 1894 only meter subscriptions are allowed[77] for spring water which is sold at 0.35 F/m^3 with a concessional tariff for low income buildings[78].

In the first half of the 19th century landlords were not keen on subscribing domestic water connections due to the implied costs both in the initial investment[79] and in the operations as a water connection implied emptying more frequently the cesspools (*fosses d'aisance*) at the bottom of the building[80]. Later[81], with the diffusion of the sanitary tubes (*tinettes filtrantes)* such a disincentive to water connection disappeared as water consumption had no more impact on the *tinettes* emptying frequency. Landlord's resistance to domestic water connection was curbed down progressively both by the tenants demand for water connected flats and by the city economic incentives. At the end of the 1870's lower water tariffs were approved and free installation of standpipes to bring water to all floors was proposed by the

[76] Due to their significant cost, only one meter per building is set up implying that an agreement on costs' allocation has to be found among the building's inhabitants. According to Barraqué (forthcoming) users downstream of the meter might be considered as members of a "common pool" community allowing to share the bill's burden and in the same time avoiding the transaction cost of individual meters.

[77] While the number of subscriptions to the domestic water supply increased, the number of public fountains and water extraction points decreased with harsh effect on access to water for low income people (Barraqué forthcoming).

[78] Surface water was sold cheaper, roughly around 0.20 F/m^3 (Lemarchand 1923, 874)

[79] Connecting to the water network had significant initial costs of nearly three times the annual subscription fee (Cebron de Lisle 1991, 190).

[80]Indeed the costs of emptying the cesspools were the landlord's responsibility.

[81] The *Tinettes filtrantes* were authorized and became more frequently used after 1851 (Jaquemet 1979).

city to all un-connected building owners engaging themselves in a minimal annual water subscription (Bocquet, Chatzis, and Sander 2008, 8).

As soon as the landlords' opposition to water connection had been curbed down a new controversy arose with the *tout-à-l'égout* issue (refer also to Box 3 in next paragraph). Landlords were harshly opposed to such a change since it would imply a sanitation levy *(taxe sur les tuyaux de chute)* based on the property value which they considered as an "unequal" progressive tax which would increase sanitation charges from 0.75 to 1.75 % of the gross property revenue (Jaquemet 1979, 536). Notwithstanding the various oppositions, the 1894 *tout-à-l'égout* law was approved: a sanitation levy[82] had to be payed by all owners of buildings with a sewer nearby[83]. The tax amount was based on the after tax net revenue and was not very progressive (from 10 to 1500 Francs)[84]. The *tout-à-l'égout* was progressively extended to all buildings. The connection's rhythm was however quite slow. Indeed, by 1913 one building out of three had not yet adopted the *tout-à-l'égout* sytem.[85]

With the 1894 law, not only did the sanitation service start to produce some revenues but also the water service's revenues were increasing since subscription to the water service was made compulsory too[86]. Incredibly the 1894 water tariff (0.35 F/m^3) was kept constant until 1920 when a new tariff of 0.65 F/m^3 was approved (Lemarchand 1923, 874). Due to the huge inflation of those years, in 1925 and 1926 new administrative acts[87] settled that water price should be indexed-link to coal and salaries. Indeed water tariff increased significantly from 1.05 F/m^3 in the first semester of 1925 to 1.46 F/m3 in 1928[88]. In the next paragraph we will analyze more deeply the financial equilibrium of the water and sanitation service. While in paragraph 6.3 we will analyze the role played by inflation.

6.2 Financial flows of the water and sanitation services

A simplified model to analyse the data

[82] The tax is called « *Taxe municipale sur les tuyaux de raccordement à l'égout »* in the 1894 law.
[83] Décision of the city's council January 27th 1892 (Bellanger, Pineau, and SIAAP 2010, 85).
[84] The minimal annual tax of 10 F had to be payed for a building having a revenue lower than 500 F. A maximum tax amount of 1500 F had to be payed for a building having a revenue higher than 100 000 F (Cebron de Lisle 1991, 648). The tax rate appear to be higher for low revenue buildings than for high revenue ones (2% and 1.5%) respectively.
[85] 24 000 out of 71 000 total buildings in Paris.
[86] Officially water subscription was made compulsory to ensure a sufficient fluidity to the sewer system but an implicit objective was also to improve the financial equilibrium of the water service (Bellanger, Pineau, and SIAAP 2010, 84)
[87] « *Arreté reglementaire* » du 11 juillet 1925 et du 21 aout 1926
[88] Archives Departementales de Paris, archival reference 2709W 24, « *liasse* 8 »

In the previous paragraph we have discussed how water and sanitation revenues were collected. In this paragraph we will analyse the global picture of Paris WSS's financial flows. The institutional scheme and the associated financial flows (1894-1925) are schematized in the following figure. Water, sanitation and canals were municipally managed and their budget was part of the city's general budget (the grey shaded area in the figure below). We analysed various years of the city's annual financial report. We adopted the classical 3 T's OECD approach in our analysis and built a simple model to analyse the cost sharing between the Tariff revenues and the Tax revenues. The city's annual financial report (*Compte administratif de l'année*…) included distinct chapters for water, sanitation and canals[89]. The city's annual financial report in those years adopted a very classical accounting scheme: *Recettes* (receipts) and *Dépenses* (expenses) which are subdivided into *ordinaires* and *extraordinaires* ones.

Revenues coming from "Tariffs" in those years were coming from the domestic water users through water billing, from the canal navigation users and from the landlords which were paying a sanitation levy. Although such a levy was very similar to a property tax, we argue that to our purpose it can be considered as a contribution to the "Tariff" part of the revenues. Doing so, we agree with Massarutto[90] (2002; 2007) and inspire our analysis from the accounting scheme he proposes. Additional (minor) revenues were also coming from the phone and telegraph servitude fees[91] and from the amounts paid by the outskirts districts which were partially discharging their waste water into the city of Paris's sewers near *Achères*[92].

On the costs side three main categories should be distinguished: Operation and Maintenance (O&M), the debt service and new investments expenditures. Concerning the two first categories, only a fraction of those costs was accounted for in the water, sanitation and canals

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[89] Depending on the year, the Water, Canals and Sanitation have one distinct chapter in the *Compte administratif de l'année* or not. In the 1910 edition, Water and canals have one subsection and sanitation has a second subsection within the same chapter (chapter 17 in expenses and chapter 21 in receipts). In the 1920 and 1925 1930 editions Water, Sanitation and canals have distinct budgetary chapters (water - chap 35, sanitation - chapter 36 and canals – chapter 37) within the "industrial services" (*services industriels)* part of the municipal financial report. In the 1930 edition Water and sanitation are together in chapter 35 while Canals is separately accounted for in chapter 36.

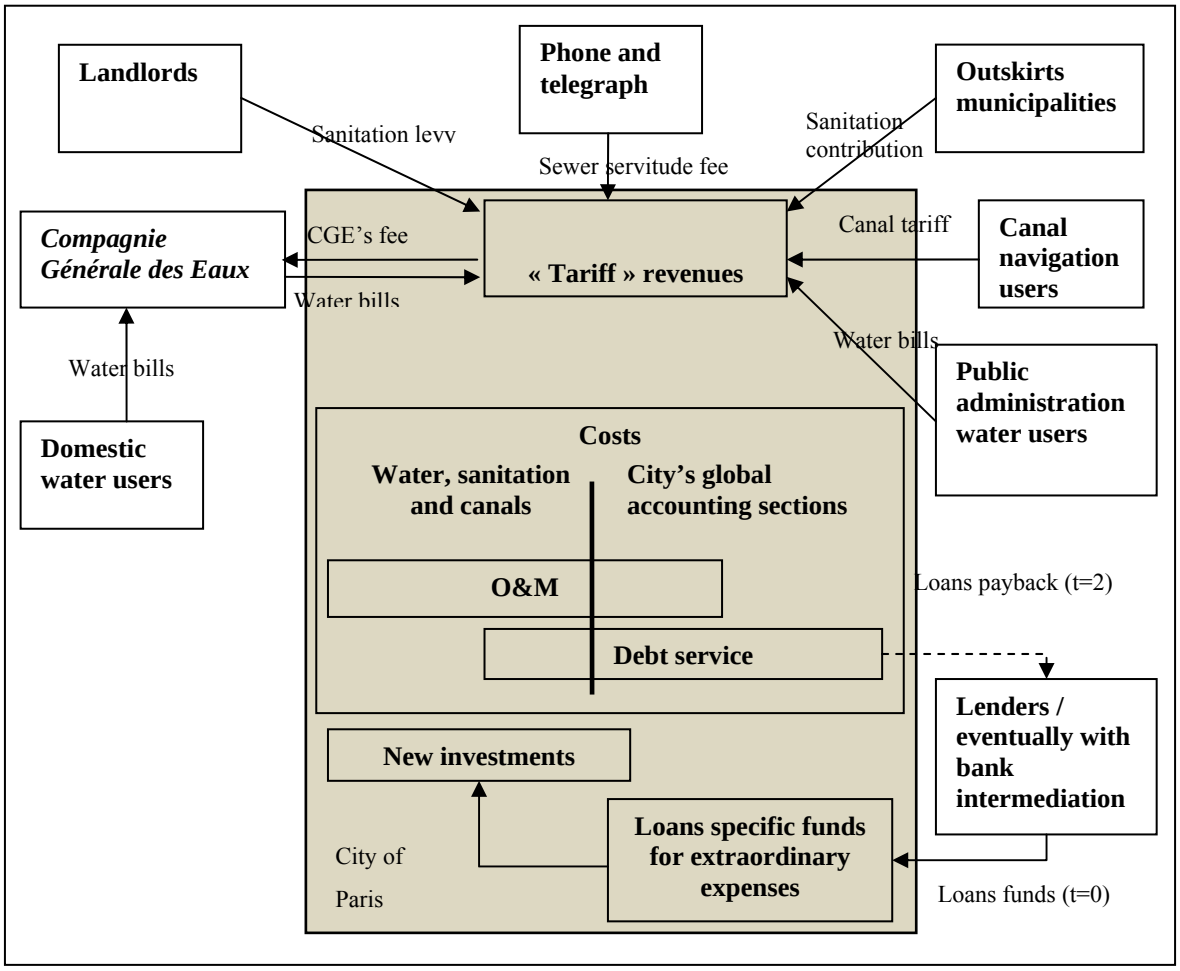
[90] "It is often a pure terminologic convention that of considering revenues either as direct charges or taxation. What really matters is who pays, for what purpose and how much, and what is the customer actually obtaining in exchange of what is paid."(Massarutto 2002, 25)

[91] 1.45 MF in 1910

[92] 139 183 F in 1910, *Note à l'appui du compte 1910*

(WSC) chapter of the city's financial report, part of them was mixed up in the various global chapters of the city's budget. For example most of the debt service expenditures were accounted for in a global expenses chapter (chapter 3). Only the royalties paid to the CGE[93] and to the former private companies concessionnaires of the canals[94] and the 31 MF 1908 water loan debt service charge are accounted for within the WSC ordinary expenses chapters.

Figure 4 : Institutional scheme and financial flows of Paris's WSS (1894 1925)



Source : author's elaboration

O&M expenses too were partially accounted for in the WSC ordinary expenses chapters and partially mixed up in various global expenditures chapters. We will refer to these latter parts of the expenses as "external O&M costs". Prior to 1920, it is almost impossible to put a figure on those external O&M costs. In the 1920, 1925 and 1930 years, some expenditures are still

[93] CGE :50 annual installments of 1 600 000 F to be paid until 1910

[94] *Saint Maur* water unit : 125 000 F until 1914, Canal *Saint Martin* 180 000 F until 1922 (Morizet 1932, 329) ; *Ourcq* and *Saint Denis* canals 540 000 F. Details on the 1864 *Saint Maur* concession are given in Bezançon (1999, 133)

mixed up in the global expenses chapters but they are also estimated and mentioned in the WSC chapters. It appears that O&M external costs, unaccounted within the WSC chapters, include a significant part of the Human Resources (including all the engineers' salaries) and of the energy costs.

What about the very large investments expenses which we described in the previous section. These were accounted for in a separate section[95] mentioning clearly on which loan funds they should be paid. No accounting depreciation was in use. Thus, it makes sense in our analysis to account for investment costs only through the debt service section of our model. To make an estimation of the debt service amount we have realized a simplified model based on the loans issued by the city. Only the capital fractions of the loan having financed water and sanitation investments have beeen considered (refer to Annex 2). Effective interest rates and maturities are taken from Table 18. Debt's redemption is considered linear and with no grace period[96]. Such a model is too simple to fully represent the complexity of the city's debt service as Table 21 shows. The model underestimates debt service when compared to the figures given by the city's annual financial report for the 1920,1925 and 1930 years. However we will show that such a model is still a useful tool to get an idea of the order of magnitude and trends of the variables. The city's accounting scheme and the model we adopted in our analysis are summarized and compared in Table 19.

Results on O&M costs sharing

The principal financial results for the Water Sanitation and Canal (WSC) service are given in Table 20 and Table 21 while the detailed financial results are given in Annex 1.

It appears clearly that until 1925 "Tariff" revenues were not even sufficient to cover the Canals and Sanitation O&M costs, even without considering "hidden subsidies" (WSC O&M external costs). In the 1925 and 1930 years, "Tariff" revenues fully covered Sanitation O&M costs even taking into account external O&M costs while they covered canals[97] O&M costs

[95] *Dépenses extraordinaires affectées sur fonds d'emprunt*

[96] This is a very basic hypothesis which does not fully represent what where the loans characteristics in terms of grace period. Indeed in various cases loans were emitted with a significant grace period in order to start amortizing freshly issued loans only when past debt's amortization ended. For example this was the case for the 1910 and 1921 loans with a grace period going until 1950 and 1929 respectively. Indeed in 1929 the amortization of the 1865 loan ended while in 1950 the amortization of the 1865, 1875 and 1876 loans ended (Denais 1921).

[97] In 1930 canals "tariff" revenues increased also because it started billing Ourcq water consumption to the water service (1.67 MF). Another internal transfer is due to the water consumption by the Sanitation service to wash sewers. Those internal transfers between the services have been neutralized in our model.

only when not considering external O&M costs. By definition, costs uncovered by "Tariff" revenues are covered by the City's general budget, meaning "Tax" revenues according to the OECD definition.

Table 19 : Water, sanitation and canals accounting scheme and model (1893-1930)

Cost classification	Accounting entries in use	Content's description	Approach in our model
O&M	**Internal O&M costs :** Data in the Water, Sanitation and Canals ordinary expenses chapters	-Human resources (except engineers) -materials -Technical maintenance -CGE's fee	Summarized from the existing data in the Water, Sanitation and Canals ordinary expenses chapters
	External O&M costs : Within other chapters of the city's financial report, unknown for the 1893 - 1910 years, mentioned distinctly in the 1920, 1925 and 1930 years	-Human resources expenditures (engineers and executives) -Part of the heating and energy expenses	Unknown for the 1893 – 1910 years, mentioned distinctly in the 1920, 1925 and 1930 years
Debt service	Mainly in the city's global debt service chapter, mentioned distinctly in the 1920, 1925 and 1930 years	All loans except the ones listed below	Estimated through our debt amortization model (Annex 2), data for the 1920, 1925 and 1930 used as a test (last column of Table 21)
	Partially included in the Water, Sanitation and Canals ordinary expenses chapters	Royalties paid to the CGE and to the former private companies owners of the canals and the 31 MF 1908 water loan	Included in the O&M expenses
New investments	In the water, sanitation and canals extraordinary expenses chapters - each loan has its own extraordinary expenses accounting fund		New investments are paid by extraordinary expenses funds coming from the loans subscribed. They are taken into account only through the debt service.

Source : author's elaboration

On the contrary the water service had larger "Tariff" revenues which were entirely covering internalized O&M costs. "water" revenues covered external O&M costs too in the 1925 and 1930 years and were probably large enough to cover them if they were known for the 1893, 1899 and 1910 years too[98].

[98]However "Tariff" revenues were not covering the full O&M costs including O&M external costs in 1920.

Observing the global picture of the Water, Sanitation and Canals chapters, total "Tariff" revenues were covering full O&M costs (including external O&M costs)[99]. Were the total "Tariff" revenues large enough to cover the debt service too ?

Table 20 : Revenues and O&M costs of the Water, Sanitation and Canals services (1893-1930), all figures in MF.

years	Water total revenues	Water O&M expenses	Water external O&M costs	Sanitation revenues	Sanitation expenses	Sanitation external O&M costs	Canals revenues	Canals expenses	Canals external O&M costs
1893	14. 2	4.7		1.7	5.3		1.1	0.97	
1899	19.1	5.8		3.7	3.1				
1910	26.1	10.9		6.7	8.2		1.2	1.1	
1920	41.4	27.9	37.7	10.5	19.8	25.5	1.2	3.3	1.5
1925	107.1	42.6	11.8	31.5	24.4	11.1	2.7	2.6	0.96
1930	248.4	78.8	32.3	57.8	35.4	15.2	5.6	4.6	2.1

Source : author's elaboration based on Paris's city annual financial report.

Results concerning the debt service's cost

Total "Tariff" revenues minus total internalized O&M costs can be defined as "Total Gross Profit A" while we will refer to Total "Tariff" revenues minus total full O&M costs (including external O&M costs) as "Total Gross Profit B".

In 1899 Total Gross Profit A (13 807 809 F) is high enough to cover the debt service amounts (10 708 081 F) estimated by our model[100]. However, if 1899 Total Gross Profit B (by definition lower than Gross Profit A since it includes full O&M costs) was known it would probably not allow to cover the debt service. Furthermore our 1899 debt service amount (10 708 081 F) appear to be an underestimation of the annual 13 MF capital expenditures mentioned by Bechmann (Paris 1900)[101]. Under Bechmann estimation concerning debt service, there is reasonable proof that in 1899 WSC "Tariff" revenues were sufficient to cover internal O&M costs and the debt service but were not high enough to cover external O&M costs too (engineers' salaries and energy mainly). In those years "Tariff" revenues were covering significant costs of the service but "financial equilibrium" was guaranteed by

[99] Except in 1920, as mentioned in the above footnote. 1920 data on external O&M costs might be not fully reliable as figures seem excessives.
[100] Similar results are estimated for the 1893 year too.
[101] Bechmann estimated the capital assets value as 300 MF on which a 4.4% rate (globally representing interests and capital payoff) gives 13 304 000 F. Our model probably underestimates capital expenditures as we have only 234 MF capital assets in 1899. Indeed, an additional simulation with a 66 MF "virtual" loan in 1865 (5% interest rate, 44 years duration) gives a debt service's estimation (13 033 081 F) very close to Bechman's one.

external O&M costs being absorbed by the city's global budget in what would be considered as "Tax" subsidy in the OECD 3T's methodology.

Between 1899 and 1930, Gross Profits A and B increased significantly while the debt service's order of magnitude was quite constant. Progressively Gross Profits B were high enough to cover the debt's service cost meaning that "Tariff" revenue was covering the full financial cost of the service with no more contributions from "Tax" revenues. Next paragraph will focus on the key role played by inflation in modifying significantly the ratio between debt service's cost, O&M costs and "Tariff" revenues.

Table 21 : Total Gross Profits of the Water, Sanitation and Canals services (1893-1930) and debt service charges ; all figures in Francs.

year	Total Gross Profit A	Total Gross Profit B	Debt service model	Debt service model with a virtual 66 MF loan in 1965	Debt service (historical data)
1893	5 961 850		5 154 088	7 929 088	
1899	13 807 898		10 708 081	13 033 081	13 000 000
1910	13 824 411		9 386 544	9 386 544	
1920	2 083 763	-62 625 453	8 939 289	8 939 289	12 308 390
1925	71 672 062	47 779 167	15 954 209	15 954 209	20 987 168
1930	193 009 313	143 284 716	14 347 347	14 347 347	19 565 629

Source : author's elaboration.

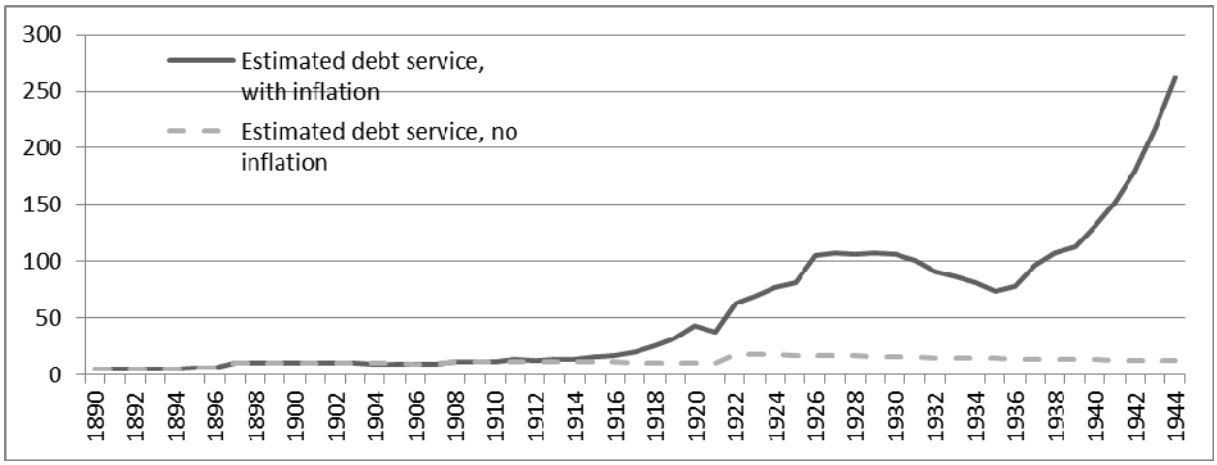
6.3 The key role of inflation

We saw in the previous paragraph that the debt service's amount, while staying almost constant, represented progressively a lower percentage of the water, sanitation and canals budget. Indeed Tariff revenues and O&M expenses increased significantly in those years while debt service stayed nearly constant. Inflation has played a key role in the borrowing-lending relationship in determining *in fine* the cost-sharing equilibrium between the lender and the borrower. Indeed, all the loans issued by the city of Paris in those years had a fixed rate and most of them had long payback durations between 60 and 75 years. The great inflation rate of the 1910-1930 years in France had the effect of absorbing a significant part of the debt's residual burden[102], transferring it, from a long run point of view, away from the

[102] Guerin-Schneider (2011) confirms our assumption and referring to the 1900-1940 years states that "the major part of the investments in the water industry in France were financed through fiscal sources and through inflation. Guerin-Schneider adds that a financing through inflation implies a social redistribution from the rich to the poor. In our opinion the distributional effect would need further enquiry to be proved. First of all who were the lenders of that time : very rich capitalists or small middle class savers as Gallais-Hamonno (2007) states for the Paris case ?

borrower on the lenders[103]. The graph below compares the real debt service with no inflation and a "virtual" debt service increased by an inflation index[104] as if the payback were indexed-link to inflation. While until 1912 inflations has a minor role (the two functions are very close), after 1912 French annual inflation rates increased significantly and debt service with inflation diverts from the no inflation curve. The area between the two curves which goes increasing is a good proxy of the lenders progressive absorption of significant part of the debt's service in real terms.

Figure 5 : Estimated debt service in MF (1890-1944), comparison with or without inflation



Source : author's elaboration, results from the model

Indeed, as the Table 22 shows, total inflated debt service represents roughly 120 MF over the 1900-1909 decade while it represents more than 800 MF over the 1920-1929 decade, meaning that in real terms a significant part of the debt's burden has been absorbed by the lenders which happen to have made a very poor placement. In terms of long run cost-sharing equilibrium, inflation has played a key role since part of the capital costs have been taken away from the water, sanitation and canal budget.

[103] Of course this a schematic view: "the lender" is a virtual entity as the bonds were exchanged on the market.
[104] The inflation index is on an 1890 base (equal to 1 in 1890) and comes from Piketty (2001 annex F), inspired from INSEE, *Bulletin Mensuel de Statistique*, février 1999, pp.144-145 ("coefficient de transformation du franc d'une année ancienne en franc")

Table 22 : Total debt service over revolving periods of 10 years, comparison with or without inflation

Years	(i) Total debt service, no inflation (MF)	(ii) Total debt service, with inflation (MF)	Difference (iii)=(ii-i)
1890-1899	97.82	96.76	-1.06
1900-1909	123.09	120.61	-2.48
1910-1919	111.06	206.22	95.16
1920-1929	163.10	860.23	697.13
1930-1939	143.68	960.26	816.58

Source : author's elaboration, results from the model

6.4 Long run cost allocation

In the previous paragraphs we have described the way through which water and sanitation revenues were collected (6.1), afterwards we have analyzed the global financial flows of the water, sanitation and canals service (6.2) and the effect of inflation (6.3). It's time now to go back to the long-distance aqueduct example introduced at the beginning of this section.

Not only long-distance aqueducts but also many other water and sanitation investments have been financed on municipal bonds issued on a long maturity at fixed interest rate (as we have shown in section 5). What was the long run end payer associated to such a short run financing solution? We have shown in paragraph (6.2) that costs were partially covered by tax-payers and users (in the 1893-1910) years and progressively covered by "Tariff" revenues only (1920-1930). We also showed in paragraph (6.3) that lenders absorbed a significant part of that debt's burden through the effect of inflation in the 1910-1930 years.

A loan is only one of the possible "*short run financing solutions*" through which water, sanitation and canals infrastructure has been financed in Paris. Table 23 summarizes the various key short run financing solutions detailing the "long run end-payer". To tackle the sustainability issue connected to these huge investments we also sketched in the third column of the following table what could be the intergenerational effect of the various possible combinations.

According to the schematization of the following table let us analyze briefly what was the cost allocation in the long run for each of the cases described in the previous sections. The cost of the first phase of the Ourcq project (paragraph 3.1) was clearly supported by the local tax payer "of today" (of the time) since no borrowing was made and since the canal was not yet producing any revenues. Since the principal fiscal source consisted in consumption taxes, in terms of equity, distributive effects are relevant (Box 1).

In the second phase of the canal development the concession approach was chosen (paragraph 3.2) together with the payment of a time-spread grant. In the same time a borrowing operation

took place (rent emission). On the short term basis the private company is financing all the expenses which will be paid back by the public grant and by future revenues from navigation tariff. The user of the canal (navigation) and the local tax payer of tomorrow are the end-payers[105]. Since the concession was bought back by public authorities (paragraph 3.3), the final cost allocation was different with a much larger part of the costs weighing on the tax payer (less navigation after the roofing of the canal Saint Martin).

Table 23 : Cost-sharing in the short run and in the long run

Short run financing solution	**Long run end-payer**	**Intergenerational effect**	**comment**	**Paris example**
Borrowing	User of tomorrow	The generation of tomorrow will pay for today's investments	if repayment comes from service revenues	Large strategic water supply and sanitation investments
	National or Local Tax Payer of tomorrow		if repayment comes from fiscal revenues	
	Lenders	The lender of today is paying since he will be repayed tomorrow in money with lower value.	In the case of larger than expected inflation and fixed interest rate	
Grant (public funds)	Tax payer	The tax payer of yesterday and today is paying		Ourcq phase 1
Public water authority equity	User	The user of yesterday and today is paying	In the case of a private investors, he will expect some returns on equity which will be payed by users of tomorrow	
Concession / private investor	Users	User of tomorrow is paying (navigation user)		Ourcq phase 2 (navigation revenues)
	Tax payers	It could be repayed by the tax payers of today (initial grant) or of tomorrow (future grant)	Applies if a grant element is associated with the concession	Ourcq phase 2 (initial grant and annuity)
	Concessionaire /private investor		This case occurs if the revenues are lower than expected or also if the revenues are not inflation –adjusted and inflation is higher than expected.	
Integrated urban development mechanisms	Owner / tenant	The generation of tomorrow is paying either through purchase price (owner) or through rent value (tenant)	Clearly investments burden is taken away from the water service. It is unclear however what was the cost allocation between the developer, the owner and the tenant.	Water supply and sewer systems in the framework of Paris's urban transformation

Source : author's elaboration

What about the long run cost allocation for the network investment financed in Haussmann's era through integrated urban development mechanisms? Infrastructure investment costs (including water and sewer systems) were absorbed in the global cost of each urban

[105] The intergenerational equilibrium in the cost allocation has also been determined by inflation.

renovation operation. In the short run these costs were financed by private developer contractors and banks while we make the hypothesis that in the long-run they were partly covered by the owners and/or the tenants of the new houses through the real-estate value chain. It is nearly impossible to determine which part of the cost was borne by the developer (if the operation was not profitable as expected), by the new owner (through the purchase value) or by the tenant (making the hypothesis that the rent value includes a part of the urban infrastructure costs). However it is clear that these costs were not supported by the municipal budget or by the water service revenues, they were rather borne by the inhabitants (tenants or owners) of the flats in renovated areas. It could be argued that the "inhabitants" category of people overlaps very much with the "water users" category and that these people were at some point paying a "water levy" through the real estate value chain (rent and/or purchase value). One could think that whether the costs were borne by "inhabitants" or by "water users" is not relevant since they are overlapping categories, on the contrary we argue that it is a key issue to address from a distributional point of view.

7 Conclusion

Major water infrastructures in Paris were brought to completion by 1925 in Paris. Most of them, such as the gravity aqueducts, the storage units and the integrated sewer-supply networks are still in operations nowadays to deliver and collect water. The canals are not anymore a source of drinking water but are still in use for leisure and constitute a key element in the urban geography of Paris.

Through a review of the major investments undertaken in water infrastructures we have analyzed a great variety of financing solutions: from fiscal resources to private concession, from bond emission to integrated urban development mechanisms. We explored and schematized for each kind of financing scheme what has been the long run cost allocation according to the various institutional solutions.

To tackle such an issue we undertook a deep analysis of the financial flows of the water, sanitation and canals (WSC) service from 1893 to 1930 using the city's annual financial report as the major primary source of data. Total costs (including O&M and debt service) were only partially accounted for within the water, sanitation and canals accounting chapter. Such a tight accounting interlocking between the WSC services and the municipality general budget is a sign *per se* that those services were managed as ordinary municipal departments even if they were labelled as "*services industriels et commerciaux"*. Such an industrial and

commercial feature is at least partially visible in the water service at the beginning of the 20th century as the water "Tariff" revenues were high enough to cover total O&M costs. On the contrary in the same years the canals and sanitation "Tariff" revenues were even below total O&M costs.

In addition to that we also showed through our debt service model that water, sanitation and canals total "Tariff" revenues were only partially sufficient to cover full costs (including debt service) implying indeed that "Tax" revenues were contributing too to the Debt's service coverage at least until 1912. Millward (2000, 329) describes a similar situation for water services in Great Britain which "made large operating surpluses but where usually not enough to meet loan charges".

Getting back to the Paris case, after 1912 things changed since the debt service stayed roughly constant while the revenues and other costs were increasing due to the high inflation of those years. The joint effect of high inflation and fixed interest rate long term loans lightened very significantly the municipality debt's service in real value. The debt service represented the same order of magnitude of the total gross profit in 1910 while it was representing only one tenth of it by 1930. Indeed long term debt and inflation absorbed a huge part of the investment amortization costs.

Another striking result of our case study is the essential difference in the chosen financing policy between lump-sum investments such as aqueducts or water treatment plants and networks. Not only network investments can be easily spread over time and at least partially absorbed by ordinary budget surplus but also they appear to be intimately linked with the urban transformation of the city.

It is common for urbanists to consider the fluid networks as the blood vessels which bring life to the city. Victor Hugo referring to Paris urban transformation wrote that "*Every time that* the *city cuts a street*, *the sewer stretches out an arm*".[106] Our study shows that on the financial side too the water and sanitation networks' extension was narrowly related to the city's urban transformation as a significant part of them was financed through integrated urban development mechanisms based on land value capture.

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[106] *« Chaque fois que la ville perce une rue, l'égout allonge un bras »,* Victor Hugo, *Les Misérables,* quoted by (Cebron de Lisle 1991, 678)

In terms of cost-sharing in the long run it appears that both inflation and the use of integrated urban development financing tools allowed to "externalize" out of the water and sanitation budget a considerable part of the investment costs and made easier for the water service to reach financial equilibrium.

Various patterns in the financing history of Paris water infrastructure seem recurrent paradigms in water infrastructure finance in France. We showed for instance that although water and sanitation were municipal services, the central state exherted a tight control on the municipality since parliamentary and administrative acts were required to approve city's loans and works. Indeed it was only with the 1980's decentralisation laws that the French State accepted to loosen its tight control on municipalities' finance[107].

We also saw that funds allocated by the city's council to the water sector were often below its financing needs since investments in other sectors was considered more urgent. Even nowadays in many local authorities in France water infrastructure financing needs are revised downwards since loans issued are uppermost allocated to other municipal sectors, not least to finance investments which are more "visible" politically (tramway lines, stadium...)[108].

The use of "integrated urban development mechanisms" as major financing tools for urban infrastructures appear to be another recurrent paradigm in urban development. In more recent years similar schemes were adopted to finance urban infrastructures integrated in urban renovation operations such as in the French scheme of the *Zone d'Amenagement Concerté* (ZAC).[109] Financing municipal investment through the mechanisms of urban development and real-estate added value capture is a very popular public policy choice recommended by international donors (Paulais 2012a; Paulais 2012b). According to this view a city can capture a part of the added value created by correctly managed urban development and use this money to finance further urban development projects or municipal investments including water and sanitation infrastructure.

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[107] *A priori* control by the French parliament was then replaced by *a posteriori* control exherted by the regional accounting offices (*Chambres Régionales des Comptes)*.

[108]Data coming from various interviews undertaken by the author in October 2011 in the framework of the ASTEE (*Association Scientifique et Technique de l'Eau et de l'Assainissement*) asset management working group.

[109]In the ZAC which were undertaken in Paris after the 70's the networks reshaping costs were sometimes financed by the water operator (in fine by all the users) and sometimes covered by the developer contractor (that is to say by the expected gain on real estate value)

In the early 20th century in Paris both "Tax" and "Tariff" revenues were used to cover water infrastructure investments costs. In 1992 the "water pays water" (*"L'eau paie l'eau")* paradigm was implemented in France and a few years later full cost recovery was implemented at the European scale too through the 2000 water framework directive. Although international institutions softened their position on the issue of full cost recovery (according to the 3T's paradigm), revenues coming from Tariff are still considered more legitimate than the others two T's[110].

Nowadays investments required in water and sanitation services in France are huge both due to the infrastructure renewal's burden and to the increasingly demanding environmental and sanitary standards. In addition to that, in the context of the 2011 sovereign debt's crisis, French water and sanitation services (WSS) are faced with a severe reduction in the access to bank credit. It is in particular very tricky in 2012 for WSS to obtain loans with maturities longer than 10-15 years which are unsatisfying for long lasting infrastructure such as the water and sanitation ones. To think that water investments were financed to a large extent with very long maturities reaching 75 years might be breath-taking for many CFO within the French water sector.

Nowadays the financial equilibrium of water and sanitation services in France is severely challenged. A rich policy debate is taking place: should the French water sector go back to a different mix of the 3 T's source of revenues ? For example various policy makers wish the "Tax revenues" to cover the costs of rain water collection and treatment. Indeed a trend in favour of a different mix of water Tariff and Tax revenues is noticeable in the French water policy debate. Will the financial flows of the water sector in France in a few years have similarities with the early 20th century picture ?

[110]During the opening speech at the Marseille 2012 World Water Forum it has been declared by Angel Gurria, General Secretary of OECD, that there is "the need to take a strategic approach to financial planning, to encourage greater use of water pricing and to enhance the use of water tariffs as a central part of what we call the 3Ts – Tariffs, Taxes and Transfers" (Gurria 2012).

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ANNEX 1 : Financial Flow of the Water, Sanitation and Canals service (1893-1930), author's elaboration

	(a)	(b)	:c	(d)	:e	f	g	h
years	Public buildings water revenues	Domestic users water revenues	Water total revenues	Water O&M expenses	Water external O&M costs	CGE's fee	Water gross profit A	Water gross profit B
1893	1 362 117	12 844 684	14 206 801	4 764 582		1 625 868	9 442 219	
1899	1 995 359	17 122 401	19 117 760	5 835 992		1 864 000	13 281 768	
1910	2 444 298	23 689 165	26 133 463	10 976 375		2 182 700	15 157 088	
1920	3 495 960	37 926 843	41 422 803	27 894 536	37 691 722	1 604 518	13 528 267	-24 163 455
1925	9 634 803	97 494 146	107 128 949	42 647 138	11 843 998	4 312 660	64 481 811	52 637 813
1930	20 268 381	228 122 000	248 390 381	78 783 818	32 375 410	8 245 156	169 606 563	137 231 153

	i	j	k	l	m	n	o	p	q	r
years	Sanitation revenues	Sanitation O&M expenses	Sanitation external O&M costs	Sanitation Gross Profit A	Sanitation Gross Profit B	Canals revenues	Canals O&M expenses	Canals external O&M costs	Canals Gross Profit A	Canals Gross Profit B
1893	1 709 000	5 369 140		-3 660 140		1 147 771	968 000		179 771	
1899	3 678 630	3 152 500		526 130						
1910	6 738 113	8 237 649		-1 499 536		1 279 859	1 113 000		166 859	
1920	10 525 793	19 836 493	25 510 651	-9 310 700	-34 821 351	1 207 724	3 341 528	1 506 843	-2 133 804	-3 640 647
1925	31 512 318	24 445 936	11 090 979	7 066 382	-4 024 597	2 685 389	2 561 520	957 918	123 869	-834 049
1930	57 802 952	35 423 470	15 274 225	22 379 482	7 105 257	5 651 682	4 628 414	2 074 962	1 f023 268	-1 051 694

1893 data from the *Note à l'appui du compte de dépense ;* 1899 data from (Cebron de Lisle 1991, 669) and (Lemarchand 1914, 165) ; 1910 data from *Note à l'appui du compte de dépense ;* 1920,1925 and 1930 data from the *Compte administratif de la ville de Paris de l'année…*

Columns :

(a) Public buildings water revenues (regie directe) ; includes "recette d'ordre" of municipal buildings water consumption

(b) Gross domestic users water revenues collected by CGE, CGE's fee has not already been deducted

(c) Water total revenues :c=(a)+(b)

(d) Water O&M expenses within the WSC chapter - includes CGE's fee and annual installments due to CGE and former canals concessionaires for the 1910-1920-1925-1930 years - After 1908 it also includes debt service concerning the 1908 water loan

(e) External O&M costs not included in WSC chapters

(f) CGE's fee, already included in (d)

(g) Water gross profit A: g = c-d

(h) Water gross profit B : h = g-e

(i) Sanitation revenues

(j) Sanitation expenses

(k) Sanitation external O&M costs

(l) Sanitation Gross Profit A l=j-i

(m) Sanitation Gross Profit B m=l-k

(n) Canals revenues

(o) Canals expenses

(p) Canals external O&M costs

(q) Canals Gross Profit A q=o-n

(r) Canals Gross Profit B r=q-p

Annex 2 : debt service model

loan year	**1860**	**1865**	**1872**	**1886**	**1894**	**1896**	**1908**	**1910**	**1921**
WSS amounts (MF)	27.5	30	19.5	60	27	117.5	31	17	107.7
duration (years)	37	63.5	20	75	79	77	53	80	61
interest rate (%)	4	5.09	5.99	3.88	3.63	3.45	3.783	3.59	5.75
capital amortization (MF)	0.74	0.47	0.97	0.8	0.34	1.52	0.58	0.21	1.76
last payback	1897	1929	1892	1961	1973	1973	1961	1990	1982

Inputs of the debt service model, annual linear amortization, no grace period. A simulation without the 1908 loan has been undertaken too since the 1908 debt service was already taken into account in the O&M expenses.

The inflation index is on an 1890 base (equal to 1 in 1890) and comes from (Piketty 2001 annex F), inspired from INSEE, Bulletin Mensuel de Statistique, février 1999, pp.144-145 ("coefficient de transformation du franc d'une année ancienne en franc")